(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 0 957 253 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
**13.10.2010 Bulletin 2010/41**

(21) Application number: **97946094.6**

(22) Date of filing: **03.12.1997**

(51) Int Cl.:
***F02D 41/38*** *(2006.01)* ***F02D 41/14*** *(2006.01)*
***F02D 43/00*** *(2006.01)* ***F02M 25/07*** *(2006.01)*
***F02D 21/08*** *(2006.01)* *F02D 35/02* *(2006.01)*

(86) International application number:
**PCT/JP1997/004433**

(87) International publication number:
**WO 1998/026169 (18.06.1998 Gazette 1998/24)**

(54) **COMBUSTION CONTROL DEVICE FOR INTERNAL COMBUSTION ENGINE**

GERÄT ZUR STEUERUNG DER VERBRENNUNG FÜR EINEN VERBRENNUNGSMOTOR

DISPOSITIF DE REGLAGE DE COMBUSTION POUR MOTEUR A COMBUSTION INTERNE

(84) Designated Contracting States:
**DE FR GB**

(30) Priority: **13.12.1996 JP 33365596**
**19.12.1996 JP 33978096**

(43) Date of publication of application:
**17.11.1999 Bulletin 1999/46**

(60) Divisional application:
**09155615.9 / 2 067 972**

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EP 0 957 253 B1

Printed by Jouve, 75001 PARIS (FR)

## Description

### TECHNICAL FIELD

**[0001]** The present invention relates to a combustion control device for an internal combustion engine where part of the exhaust gas output from an exhaust system of the internal combustion engine is recirculated into an intake system of the internal combustion engine.

### BACKGROUND ART

**[0002]** Conventionally, in general car engines, fuel is injected from a fuel injection valve into an intake port, so that a homogeneous mixture of the fuel and the air is supplied to a combustion chamber. In such engines, an intake path is opened or closed by a throttle valve which is activated in response to the operation of an accelerator. The opening or closing of the intake path serves to adjust the amount of intake air (resultantly, the amount of the homogeneous mixture of the fuel and the air) supplied to the combustion chamber of the engine, thus to control the engine power.

**[0003]** In such a so-called homogeneous burning technique, however, a large intake negative pressure is generated due to the throttling operation of the throttle valve, thereby increasing pumping loss and reducing the efficiency. A technique called "stratified burning" which overcomes the above problem is known, where the throttling of a throttle valve is reduced and fuel is directly supplied to a combustion chamber. This enables combustible mixed air to exist in the vicinity of an ignition plug, increasing the air fuel ratio in this region to improve the ignitability.

**[0004]** An engine employing the above technique is provided with a fuel injection valve for stratified burning which injects fuel directing to the region in the vicinity of the ignition plug. During a low load of the engine, fuel is injected from the fuel injection valve for stratified burning so that the fuel is locally supplied in the vicinity of the ignition plug. Simultaneously with this local supply of the fuel, a throttle valve is opened, to realize the "stratified burning" described above. This enables reducing fuel consumption as well as reducing pumping loss.

**[0005]** Such an engine is provided with an exhaust gas recirculation (EGR) mechanism to achieve emission reduction, as in a device described in Japanese Laid-Open Publication No. 7-119513, for example. Such an EGR mechanism includes an EGR path for associating an exhaust path and an intake path of the engine with each other and an EGR valve for opening or closing the EGR path. When the engine operates in a low load range, the opening/closing of the EGR valve is controlled so that as the load increases the amount of exhaust gas to be recirculated (the EGR amount) is reduced. This control enables reducing the air excess rate and thus improving the performance of cleaning of nitrogen oxide in a catalyst device.

**[0006]** The above publication also discloses a technique where torque variation (output variation) of an engine is approximated to a target value by controlling the EGR amount, so as to achieve both suppression of torque variation and reduction of emission. More specifically, when the torque variation exceeds a target value, the EGR amount is decreased to suppress the torque variation to below the target value. When the torque variation becomes less than the target value, the EGR amount is increased to approximate the torque variation to the target value, and thus to reduce the amount of nitrogen oxide emitted from the engine.

**[0007]** During the above "stratified burning", the relationship between the EGR amount and the torque variation is as shown in Figure **22** when the fuel injection amount is fixed. More specifically, in an area of a smaller EGR amount, the change in torque variation with increase or decrease of the EGR amount is small. In an area of a larger EGR amount, the change in torque variation with increase or decrease of the EGR amount is large. The reason why the change in torque variation with increase or decrease of the EGR amount is small in the area of a smaller EGR amount is that, since a mixed gas with a high-concentration fuel exists in the vicinity of an ignition plug in the "stratified burning", the combustion state of such a mixed gas is not easily changed with a change in the EGR amount.

**[0008]** In the above relationship between the EGR amount and the torque variation, assume that the EGR amount is at point **A** in Figure **22**. In this case, the torque variation is considerably smaller than the target value. In order to approximate the torque variation to the target value, the control is made to increase the EGR amount. This results in the torque variation shifting as shown by the solid line in Figure **22** from point **A** toward the target value, i.e., point **B**.

**[0009]** In the above case, however, the torque variation increases only at a small change rate as the EGR amount is increased in the area of a smaller EGR amount as described above. It is therefore impossible to quickly approximate the torque variation to the target value.

**[0010]** On the contrary, in the area of a larger EGR amount, the torque variation excessively shifts as the EGR amount changes. This makes it difficult to correctly control the torque variation to be approximated to the target value. To describe more precisely, due to a response delay of the change in the EGR amount, the EGR amount does not immediately change in response to a change in the opening of the EGR valve. Accordingly, when the torque variation exceeds the target value (arrow **C** in Figure **22**), the torque variation exhibits a sharp increase from the target value due to the response delay at the start of decrease of the EGR amount. Such an excessive torque variation may cause a reduction

of drivability.

**[0011]** In recent years, in order to reduce fuel consumption, the air fuel ratio of a homogeneous mixed gas to be supplied to a combustion chamber is made larger than a theoretical air fuel ratio, and swirl is generated in the mixed gas, so as to perform "lean burning".

**[0012]** During the "lean burning", as the EGR amount increases, the ignitability of the mixed gas decreases and simultaneously the flame speed in the mixed gas decreases. Accordingly, if the EGR amount excessively increases, the mixed gas may not be ignited or may fail to be burned out if ignited, resulting in increasing the torque variation of the engine.

**[0013]** During the "lean burning", also, the amount of fuel included in the mixed gas per unit volume decreases. As a result, the torque variation of the engine increases or decreases in response to a change in the fuel injection amount from a fuel injection valve. For example, the torque variation of the engine increases when the fuel injection amount falls below a required amount due to a design size tolerance for the fuel injection valve and the like. On the contrary, the torque variation of the engine decreases when the fuel injection amount exceeds the required amount due to a design size tolerance for the fuel injection valve and the like.

**[0014]** According to the above conventional technique, when the torque variation increases due to a decrease of the fuel injection amount below the required amount due to a design size tolerance and the like, it is attempted to suppress the torque variation by decreasing the EGR amount to be approximated to the target value. However, since the above increase of the torque variation is caused by the decrease of the fuel injection amount due to a design size tolerance for the fuel injection valve and the like, such torque variation is not suppressed even if the EGR amount is decreased. Surging generated in the engine due to the torque variation is not suppressed, either. Moreover, since the emission amount of nitrogen oxide ($NO_x$) increases due to the decrease of the EGR amount, emission is worsened. Document US 5 265 575 A teaches a device to adapt a fuel injection amount in a case were a torque variation falls within different ranges, that is, a second range or a third range.

**[0015]** Document DE 43 03 332 A1 discloses a controller for an internal combustion engine in which an optimum lean air-fuel mixture is determined on the basis of the ability to ignite the air-fuel mixture. If the ability to ignite the air-fuel mixture is deteriorated, that is misfire occurs, D2 teaches to correct a fuel injection amount as well as an EGR-amount.

**[0016]** It is the object of the invention to provide a combustion control device for an internal combustion engine, which can achieve a quick approximation of an output variation of the internal combustion engine to a target value while a worsening of emissions is suppressed.

**[0017]** The object of the invention is achieved by claim 1. Advantageous embodiments are carried out according to the dependent claims.

**[0018]** As shown in Figure **1**, a combustion control device for an internal combustion engine includes: fuel injection means **M2** for injecting fuel into a cylinder of an internal combustion engine **M1**; exhaust gas recirculation means **M3** for recirculating part of exhaust gas exhausted from an exhaust system of the internal combustion engine **M1** to an intake system of the internal combustion engine **M1**; output variation detection means **M4** for detecting output variation of the internal combustion engine **M1**; and control means **M5** for controlling both the fuel injection amount injected by the fuel injection means **M2** and the exhaust gas amount to be recirculated by the exhaust gas recirculation means **M3**, based on the output variation detected by the output variation detection means **M4** so as to approximate the output variation to a target value.

**[0019]** With the above configuration, fuel injected from the fuel injection means **M2** is supplied to a cylinder of the internal combustion engine **M1**, so that combustion is performed with a mixed gas composed of the fuel and the air. When the output variation of the internal combustion engine **M1** is displaced from a target value, the control means **M5** increases or decreases both the fuel injection amount injected by the fuel injection means **M2** and the exhaust gas amount to be recirculated to the intake system of the internal combustion engine **M1**, so as to approximate the output variation to the target value. In other words, the output variation of the internal combustion engine **M1** is approximated to the target value by increasing or decreasing both the fuel injection amount and the exhaust gas amount to be recirculated. Thus, the output variation can be quickly approximated to the target value.

**[0020]** In one example, the control means **M5** decreases the fuel injection amount and increases the exhaust gas amount to be recirculated when the output variation of the internal combustion engine **M1** is smaller than the target value. Also, the control means **M5** increases the fuel injection amount and decreases the exhaust gas amount to be recirculated when the output variation of the internal combustion engine **M1** is larger than the target value.

**[0021]** In general, the air fuel ratio of a mixed gas during stratified burning is larger than a theoretical air fuel ratio. Accordingly, when the output variation of the internal combustion engine **M1** is smaller than a target value, the output variation can be made large by decreasing the fuel injection amount. At this time, the output variation also becomes large by increasing the exhaust gas amount to be recirculated because the ignitability and the flame speed of the mixed gas decrease. This means that when the output variation becomes smaller than a target value, the output variation can be reliably approximated to the target value by both decreasing the fuel injection amount and increasing the exhausted gas recirculation amount. Likewise, when the output variation of the internal combustion engine **M1** is larger than a target value, the output variation can be made small by increasing the fuel injection amount. At this time, the output variation

also becomes small by decreasing the exhaust gas amount to be recirculated. This means that when the output variation becomes larger than a target value, the output variation can be reliably approximated to the target value by both increasing the fuel injection amount and decreasing the exhausted gas recirculation amount.

**[0022]** In one example, the control means **M5** decreases the fuel injection amount when the output variation of the internal combustion engine **M1** is less than the target value, and increases the exhaust gas amount to be recirculated when the output variation of the internal combustion engine falls further. Also, the control means **M5** increases the fuel injection amount when the output variation of the internal combustion engine **M1** is greater than the target value, and decreases the exhaust gas amount to be recirculated when the output variation of the internal combustion engine increases further.

**[0023]** More specifically, when the torque variation of the internal combustion engine **M1** is slightly changed from the target value on the increase side or on the decrease side, only the fuel injection amount is increased or decreased before the exhaust gas recirculation amount is increased or decreased, to approximate the torque variation to the target value. In this case, since the exhaust gas recirculation amount is not increased or decreased, emission is prevented from worsening. Also, since the fuel injection amount can be decreased without increasing the exhaust gas recirculation amount, the fuel consumption of the internal combustion engine **M1** is reduced.

**[0024]** In one example, the internal combustion engine **M1** performs homogeneous burning and stratified burning selectively, and a maximum fuel correction amount used when the fuel injection amount is corrected incrementally to approximate the output variation of the internal combustion engine **M1** to a target value during the stratified burning is set at a value smaller than a maximum fuel correction amount used when the fuel injection amount is corrected incrementally to approximate the output variation to the target value during the homogeneous burning.

**[0025]** Thus, by setting the maximum fuel correction amount used during the stratified burning at a value smaller than the maximum fuel correction amount used for the homogeneous burning, misfiring can be prevented even during the stratified burning in which a mixed gas including fuel at a high concentration exists in the vicinity of the ignition plug.

**[0026]** As shown in Figure **2**, the combustion control device for an internal combustion engine according to the present invention includes: fuel injection means **M12** for injecting fuel into a cylinder of the internal combustion engine **M11**; exhaust gas recirculation means **M13** for recirculating part of exhaust gas exhausted from an exhaust system of the internal combustion system **M11**, to an intake system of the internal combustion system **M11**; output variation detection means **M14** for detecting output variation of the internal combustion engine **M11**; injection amount control means **M15** for controlling a fuel injection amount injected by the fuel injection means **M12** based on the output variation detected by the output variation detection means **M14** so as to approximate the output variation to a target value; and recirculation amount control means **M16** for controlling an exhaust gas amount to be recirculated by the exhaust gas recirculation means **M13** based on the fuel injection amount controlled by the injection amount control means **M15** so as to approximate the output variation to the target value.

**[0027]** With the above configuration, the fuel injection amount injected by the fuel injection means **M12** is increased or decreased to approximate the output variation of the internal combustion engine **M11** by the injection amount control means **M15**. Also, the exhaust amount to be recirculated to approximate the output variation of the internal combustion engine **M11** to the target value is controlled by the exhaust gas recirculation means **M13** based on the fuel injection amount increased or decreased by the injection amount control means **M15**. This prevents emission worsening which may occur by an insufficient exhaust gas amount being recirculated.

**[0028]** In one example the injection amount control means **M15** decreases the fuel injection amount when the output variation of the internal combustion engine **M11** is smaller than the target value. Also, the injection amount control means **M15** increases the fuel injection amount when the output variation of the internal combustion engine **M11** is larger than the target value. In this way, the output variation is approximated to the target value.

**[0029]** In one embodiment of the invention, the recirculation amount control means **M16** decreases the exhaust gas to be recirculated when the fuel injection amount controlled by the injection amount control means **M15** is displaced from a predetermined range of increase and decrease on the increase side. Also, the recirculation amount control means **M16** makes larger a decrease of the exhaust gas amount to be recirculated as the fuel injection amount controlled by the injection amount control means **M15** is displaced farther from the predetermined range of increase and decrease.

**[0030]** The fuel injection amount controlled by the injection amount control means **M15** is increased or decreased with respect to a required amount due to the size tolerances of the intake system and the fuel system of the internal combustion engine **M11**. When the fuel injection amount is displaced on the increase side from the range of increase and decrease in which the fuel injection amount is increased or decreased due to the size tolerances and the like, the exhaust gas amount to be recirculated to the intake system of the internal combustion engine **M11** is decreased by the recirculation amount control means **M16**. By this control, when the fuel injection amount becomes smaller than the required amount due to the tolerances described above, increasing the output variation of the internal combustion engine **M11**, the exhaust gas amount to be recirculated will not be decreased to approximate the output variation to a target value. Also, as the fuel injection amount controlled by the injection amount control means **M15** is displaced farther from the above range of increase and decrease, the reduction of the exhaust gas recirculation amount is made larger. Accordingly, the output

variation of the internal combustion engine **M11** can be reliably suppressed even when the fuel injection amount is widely displaced on the increase side from the range of increase and decrease of the fuel injection amount due to a size tolerance and the like described above.

**[0031]** As a result, in the internal combustion engine **M11** performing lean burning, emission can be reliably prevented from worsening, which otherwise occurs because the exhaust gas to be recirculated is decreased when the fuel injection amount decreases below the required amount due to the size tolerances of the intake system and the fuel system of the internal combustion engine **M11**.

**[0032]** Furthermore, the recirculation amount control means **M16** increases the exhaust gas to be recirculated when the fuel injection amount controlled by the injection amount control means is displaced from a predetermined range of increase and decrease on the decrease side. Also, the recirculation amount control means **M16** makes larger the increase of the exhaust gas amount to be recirculated as the fuel injection amount controlled by the injection amount control means **M15** is displaced farther from the predetermined range of increase and decrease.

**[0033]** In other words, when the fuel injection amount controlled by the injection control means **M15** is displaced on the increase side from the range of increase and decrease of the fuel injection amount due to the size tolerances and the like described above, the increase of the exhaust gas amount to be recirculated is made larger as the displacement of the fuel injection amount from the range of increase and decrease is larger.

**[0034]** Accordingly, in the internal combustion engine **M11** performing lean burning, emission can be reliably suppressed from worsening even when the fuel injection amount increased or decreased by the injection amount control means **M15** is widely displaced on the decrease side from the range of increase and decrease of the fuel injection amount due to the size tolerances and the like described above.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0035]**

Figure **1** is a block diagram illustrating an exemplary concept.

Figure **2** is another block diagram illustrating a basic concept of the present invention.

Figure **3** is a schematic construction view illustrating a combustion control device for an engine.

Figure **4** is an enlarged sectional view of a cylinder portion of the engine of Figure **3**.

Figure **5** is a flowchart showing a processing routine for controlling the fuel injection amount and the EGR amount.

Figure **6** is a view explaining the method of calculating the torque variation.

Figure **7** is a graph showing ranges of the torque variation.

Figure **8** is a graph showing a relationship among the torque variation, the fuel injection amount, and the EGR amount.

Figure **9** is a graph showing another relationship among the torque variation, the fuel injection amount, and the EGR amount.

Figure **10** is a graph showing the relationship among the $NO_x$ amount, the fuel injection amount, and the EGR amount

Figure **11** is a flowchart showing a processing routine for controlling the fuel injection amount and the EGR amount.

Figure **12** is a graph showing ranges of the torque variation.

Figure **13** is a graph showing the relationship among the torque variation, the fuel injection amount, and the EGR amount.

Figure **14** is a graph showing the relationship among the $NO_x$ amount, the fuel injection amount, and the EGR amount.

Figure **15** is a flowchart showing a processing routine for controlling the fuel injection amount and the EGR amount.

Figure **16** is a learning map showing learning areas.

Figure **17** is a basic fuel injection amount map for calculating the basic fuel injection amount.

Figure **18** is a flowchart showing a processing routine for controlling the fuel injection amount and the EGR amount according to the present invention.

Figure **19** is another flowchart showing a processing routine for controlling the fuel injection amount and the EGR amount.

Figure **20** is a graph showing the relationship among the fuel correction amount, the EGR amount, and the $NO_x$ emission amount.

Figure **21** is a graph showing the relationship among the fuel correction amount, the EGR amount, and the torque variation.

Figure **22** is a graph showing the relationship among the torque variation, the fuel injection amount, and the EGR amount in a conventional engine.

BEST MODES FOR CARRYING OUT THE INVENTION

**[0036]** Hereinbelow, the combustion control device for an internal combustion engine will be described with reference to the relevant drawings, in the form of examples and embodiments according to the present invention as applied to a car engine.

(First example)

**[0037]** Figure **3** is a schematic construction view illustrating a combustion control device for a cylinder injection type engine mounted in a car. An internal combustion engine **1** includes four cylinders #1 to #4, for example. Figure **4** shows a structure of a combustion chamber of one of the cylinders #1 to #4. As shown in Figures **3** and **4**, the engine **1** includes pistons which reciprocate in a cylinder block **2**. A cylinder head **4** is disposed above the cylinder block **2**. A combustion chamber **5** is defined between each piston and the cylinder head **4**. In the illustrated device, each of the cylinders #1 to #4 is provided with four valves. In Figure **4**, first and second intake valves **6a** and **6b**, together with first and second intake ports **7a** and **7b**, and a pair of exhaust valves **8**, together with a pair of exhaust ports **9**, are shown.

**[0038]** As shown in Figure **4**, the first intake port **7a** is a helical intake port, while the second intake port **7b** is a straight port extending substantially straight. In the center of the inner wall of the cylinder head **4** is disposed an ignition plug **10**.

**[0039]** The ignition plug **10** is supplied with a high voltage from an igniter **12** via a distributor (not shown). The timing of the ignition of the ignition plug **10** is determined by the timing of the output of a high voltage from the igniter **12**. A fuel injection valve **11** is disposed at a position of the periphery of the inner wall of the cylinder head **4** near the first and second intake valves **6a** and **6b**. In other words, in the illustrated device, fuel from the fuel injection valve **11** is directly injected into each of the cylinders #1 to #4.

**[0040]** Referring to Figure **3**, the first and second intake ports **7a** and **7b** of each of the cylinders #1 to #4 are associated with a surge tank **16** via respective first and second intake paths **15a** and **15b** formed in each intake manifold **15**. Each second intake path **15b** is provided with a swirl control valve **17**. The swirl control valves **17** are coupled with a step motor **19**, for example, via a common shaft **18**. The step motor **19** is controlled based on an output signal from an electrical control unit (ECU) **30** which will be described hereinafter. The step motor **19** may be replaced with an element which is controlled in accordance with the negative pressure of the intake ports **7a** and **7b** of the engine **1**.

**[0041]** The surge tank **16** is coupled with an air cleaner **21** via an intake duct **20**. The intake duct **20** includes a throttle valve **23** which is opened or closed by a step motor **22**. In other words, the throttle valve **23** is of an electronic control type, where, basically, the step motor **22** is driven based on an output signal from the ECU **30** described above, so as to control the opening/closing of the throttle valve **23**. Depending on the opening/closing of the throttle valve **23**, the amount of intake air introduced into each combustion chamber **5** via the intake duct **20** is adjusted.

**[0042]** A throttle sensor **25** for detecting the opening of the throttle valve **23** (throttle opening) is disposed in the vicinity of the throttle valve **23**. The exhaust ports **9** of the cylinders #1 to #4 are associated with an exhaust manifold **14**. Exhaust gas after combustion is exhausted to an exhaust duct **14a** via the exhaust manifold **14**.

**[0043]** The illustrated combustion control device is further provided with a known exhaust gas recirculation (EGR) mechanism **51**. The EGR mechanism **51** includes an exhaust gas recirculation (EGR) path **52** and an EGR valve **53** disposed midway of the EGR path **52**. The EGR path **52** is disposed so as to associate a portion of the intake duct **20** downstream of the throttle valve **23** with the exhaust duct **14a**. The EGR valve **53** includes a valve seat, a valve body, and a step motor although they are not shown. The opening of the EGR valve **53** is adjusted by intermittently displacing

the valve head with respect to the valve seat by the step motor. When the EGR valve **53** opens, part of the exhaust gas exhausted to the exhaust duct **14a** flows through the EGR path **52**, to reach the intake duct **20** via the EGR valve **53**. In other words, part of the exhaust gas is recirculated into an intake mixed gas by means of the EGR mechanism **51**. The recirculation amount of the exhaust gas (EGR amount) is adjusted by adjusting the opening of the EGR valve **53.**

**[0044]** The ECU **30** is a digital computer, including a random access memory (RAM) **32**, a read only memory (ROM) **33**, a central processing unit (CPU) **34** composed of a microprocessor, an input port **35**, and an output port **36** which are mutually connected via a bus **31**.

**[0045]** An accelerator **24** for operating the throttle valve **23** is connected with an acceleration sensor **26A** which generates an output voltage in proportion to the amount of pressing of the accelerator **24**, so that the opening of the accelerator is detected by the acceleration sensor **26A**. The output voltage of the acceleration sensor **26A** is sent to the input port **35** via an A/D converter **37**. The accelerator **24** is provided with a full close switch **26B** which detects that the amount of pressing of the accelerator **24** is zero. More specifically, the full close switch **26B** generates a signal "1" as a full close signal when the amount of pressing of the accelerator **24** is zero and otherwise generates a signal "0". The output voltage of the full close switch **26B** is also sent to the input port **35**.

**[0046]** A top dead center sensor **27** generates an output pulse when the cylinder #1, for example, reaches the intake top dead center, and the output pulse is sent to the input port **35**. A crank angle sensor **28** generates an output pulse whenever a crank shaft rotates by 30° CA, for example, and the output pulse is sent to the input port **35**. The CPU **34** calculates (reads) the crank position and the number of revolutions of the engine (NE) from the output pulses of the top dead center sensor **27** and the crank angle sensor **28**.

**[0047]** The rotational angle of the shaft **18** is detected by a swirl control valve sensor **29**, to enable the measurement of the opening of the swirl control valves **17**. The output of the swirl control valve sensor **29** is sent to the input port **35** via the A/D converter **37.**

**[0048]** The throttle sensor **25** detects the throttle opening, and the output of the throttle sensor **25** is sent to the input port **35** via the A/D converter **37**.

**[0049]** The illustrated combustion control device also includes an intake pressure sensor **61** for detecting the pressure (intake pressure) in the surge tank **16**, and a water temperature sensor **62** for detecting the temperature of cooling water for the engine **1**. The outputs of these sensors **61** and **62** are also sent to the input port **35** via the A/D converter **37.**

**[0050]** The output port **36** is connected to the fuel injection valves **11**, the step motors **19** and **22**, the igniter **12**, and the EGR valve **53** (the step motor) via corresponding driving circuits **38**. The ECU **30** controls the operations of the fuel injection valves **11**, the step motors **19** and **22**, the igniter **12** (the ignition plug **10**), the EGR valve **53**, and the like in accordance with a control program stored in the ROM **33**.

**[0051]** Referring to Figure **5**, the fuel injection amount control and the EGR amount control by the combustion control device of the first example will be described. Figure **5** shows a processing routine for the fuel injection amount control and the EGR amount control, which is executed by the ECU **30** during "stratified burning". This processing routine is executed at an occasion of angle interruption for each predetermined crank angle.

**[0052]** In the illustrated processing routine, at step **S101**, the ECU **30** calculates a torque variation **dln** of the entire engine **1** based on the output pulses from the top dead center sensor **27** and the crank angle sensor **28**. The torque variation **dln** is an average value of torque variations **dln1** to **dln4** generated in the cylinders #1 to #4, which is calculated by expression (1) below.

$$dln = (dln1 + dln2 + dln3 + dln4) / 4 \qquad (1)$$

**[0053]** A torque **T** generated on each combustion in the cylinders #1 to #4 has the relationship represented by expression (2) below.

$$T \propto (30° / t_b)^2 - (30° / t_a)^2 \qquad (2)$$

wherein $t_a$ denotes the time required for the crank shaft of the engine **1** to pass a predetermined crank angle portion $\theta 1$ including the top dead center (see Figure **6**), and $t_b$ denotes the time required for the crank shaft to pass a predetermined crank angle portion $\theta 2$ rotated by 90° from the top dead center (see Figure **6**). The crank angle portions $\theta 1$ and $\theta 2$ are the same. For example, they are 30°.

**[0054]** The torque variation **dln1** generated in the cylinder #1, for example, is calculated based on the difference in the torque **T** generated on each combustion in the cylinder #1, as represented by expression (3) below.

$$dln1 = \{(30° / t_{b1})^2 - (30° / t_{a1})^2\} - \{(30° / t_{b1-1})^2 - (30° / t_{a1-1})^2\} \quad (3)$$

**[0055]** The torque variations **dln2** to **dln4** generated in the cylinders #2 to #4 are also calculated as described for the torque variation **dln1**. The torque variation **dln** of the entire engine **1** is calculated based on the torque variations **dln1** to **dln4** generated in the cylinders #1 to #4 according to expression (1) above.

**[0056]** At step **S102**, the ECU **30** determines whether or not the calculated torque variation **dln** is larger than a value obtained by adding a predetermined value **C1** to a target value **dln|v| (dln|v| + C1).** If **dln** > **dln|v|** + **C1,** i.e., the torque variation **dln** is in a range **A** shown in Figure **7**, the process proceeds to step **S103**. When the torque variation **dln** is in the range **A**, the torque variation **dln** and the EGR amount have the relationship represented by the solid line **X1** in Figure **8**, the torque variation **dln** and the fuel injection amount have the relationship represented by the solid line **Y1** in Figure **9**, and the $NO_x$ emission amount and the fuel injection amount have the relationship represented by the solid line **Z1** in Figure **10.**

**[0057]** At step **S103**, the ECU **30** sets a value obtained by adding a predetermined value **Cfuel** to a fuel correction amount **faf** used in the preceding correction of the combustion injection amount **(faf + Cfuel)** as a new fuel correction amount **faf**. The ECU **30** also sets a value obtained by subtracting a predetermined value **Cegr** from an EGR correction amount **kegr** used in the preceding correction of the EGR amount **(kegr - Cegr)** as a new EGR correction amount **kegr**. In short, at step **S103**, the fuel injection amount is incrementally corrected, while the EGR amount is decrementally corrected.

**[0058]** Assume that the EGR amount and the fuel injection amount are at points on the solid lines **X1** (Figure **8**), **Y1** (Figure **9**), and **Z1** (Figure **10**). In this case, when the fuel injection amount is increased as described above, the torque variation **dln** decreases. This is because the air fuel ratio of a mixed gas during the stratified burning is larger than a theoretical air fuel ratio. When the EGR amount is decreased as described above, the torque variation **dln** also decreases. This is because the ignitability and the flame speed of the mixed gas improve. As a result, the relationship between the torque variation **dln** and the EGR amount shifts to that represented by the solid line **X2** in Figure **8**, and point **P** on the solid line **X1** shifts toward point **Q** on the solid line **X2**. The relationship between the torque variation and the fuel injection amount shifts to that represented by the solid line **Y2** in Figure **9**, and point **P** on the solid line **Y1** shifts toward point **Q** on the solid line **Y2**. The relationship between the $NO_x$ emission amount and the fuel injection amount shifts to that represented by the solid line **Z2** in Figure **10**, and point **P** on the solid line **Z1** shifts toward point **Q** on the solid line **Z2**.

**[0059]** Thus, by both increasing the fuel injection amount and decreasing the EGR amount, the shift from point **P** to point **Q** is realized, allowing for quick reduction of the torque variation **dln**. In this way, the torque variation **dln** can be quickly and reliably approximated to the target value **dln|v|.** Due to the shift from point **P** to point **Q,** also, the target value **dln|v|** is located at point **Q** which is within an area where the torque variation does not excessively change with the change of the EGR amount. Accordingly, the increase of the torque variation **dln** is slow when the torque variation **dln** starts increasing from the target value **dln|v|** at point **Q** (arrow R in Figure **8**), ensuring that the torque variation **dln** will not be greatly displaced on the increase side with respect to the target value **dln|v|.** In addition, since the change in the $NO_x$ emission amount with the change in the EGR amount is small in "stratified burning", the $NO_x$ amount is prevented from increasing excessively with the shift from point **P** to point **Q**.

**[0060]** If it is determined that **"dln** > **dln|v|** + **C1"** is not established at step **S102**, the process proceeds to step **S104**. At step **S104**, the ECU **30** determines whether or not the torque variation **dln** is smaller than a value obtained by subtracting the predetermined value **C1** from the target value **dln|v| (dln|v| - C1)**. If **"dln** < **dln|v| - C1"** is not established, i.e., the torque variation **dln** is in a range **B** shown in Figure **7**, the ECU **30** terminates this processing routine. If **dln** < **dln|v| - C1,** i.e., the torque variation **dln** is in a range **C**, the process proceeds to step **S105**. When the torque variation **dln** is in the range **C**, the torque variation **dln** and the EGR amount have the relationship represented by the solid line **X3** in Figure **8,** the torque variation **dln** and the fuel injection amount have the relationship represented by the solid line **Y3** in Figure **9**, and the $NO_x$ emission amount and the fuel injection amount have the relationship represented by the solid line **Z3** in Figure **10**.

**[0061]** At step **S105**, the ECU **30** sets a value obtained by subtracting the predetermined value **Cfuel** from the fuel correction amount **faf** used in the preceding correction of the combustion injection amount **(faf - Cfuel)** as a new fuel correction amount **faf**. The ECU **30** also sets a value obtained by adding the predetermined value **Cegr** to the EGR correction amount **kegr** used in the preceding EGR correction **(kegr + Cegr)** as a new EGR correction amount **kegr**. In short, at step **S105**, the fuel injection amount is decrementally corrected, while the EGR amount is incrementally corrected.

**[0062]** Assume that the EGR amount and the fuel injection amount are at points **S** on the solid lines **X3** (Figure **8**), **Y3** (Figure **9**), and **Z3** (Figure **10**). In this case, when the fuel injection amount is decreased as described above, the torque

variation **dln** increases. This is because the air fuel ratio of a mixed gas during the stratified burning is larger than a theoretical air fuel ratio. When the EGR amount is increased as described above, the torque variation **dln** also increases. This is because the ignitability and the flame speed of the mixed gas become low. As a result, the relationship between the torque variation **dln** and the EGR amount shifts to that represented by the solid line **X4** in Figure **8**, and point **S** on the solid line **X3** shifts toward point **T** on the solid line **X4**. The relationship between the torque variation and the fuel injection amount shifts to that represented by the solid line **Y4** in Figure **9**, and point **S** on the solid line **Y3** shifts toward point **T** on the solid line **Y4**. The relationship between the $NO_x$ emission amount and the fuel injection amount shifts to that represented by the solid line **Z4** in Figure **10**, and point **S** on the solid line **Z3** shifts toward point **T** on the solid line **Z4.**

**[0063]** Thus, by both decreasing the fuel injection amount and increasing the EGR amount, the shift from point **S** to point **T** is realized, allowing for quick increase of the torque variation **dln**. In this way, the torque variation **dln** can be quickly and reliably approximated to the target value **dln|v|.** Due to the shift from point **S** to point **T**, also, the target value **dln|v|** is located at point **T** which is within an area where the torque variation does not excessively change with the change of the EGR amount. Accordingly, the increase of the torque variation **dln** is slow when the torque variation **dln** starts increasing from the target value **dln|v|** at point **T** (arrow U in Figure **8**), ensuring that the torque variation **dln** will not be greatly displaced on the increase side with respect to the target value **dln|v|.** In addition, since the EGR amount is increased with the shift from point **S** to point **T**, the $NO_x$ emission amount can be reduced.

**[0064]** After the processing at step **S103** or step **S105**, the ECU **30** proceeds to step **S106**. At step **S106**, the ECU **30** determines whether or not the fuel correction amount **faf** is equal to or greater than the allowable minimum value $\mathbf{faf_{min}}$ **(**$\mathbf{faf_{min} \leq faf}$**).** If **"**$\mathbf{faf_{min} \leq faf}$**"** is not established, the process proceeds to step **S107**, where the fuel correction amount **faf** is restricted by the minimum value (minimum fuel correction amount) $\mathbf{faf_{min}}$, and then proceeds to step **S110**. If $\mathbf{faf_{min} \leq faf}$ at step **S106**, the process proceeds to step **S108**, where the ECU **30** determines whether or not the fuel correction amount **faf** is equal to or less than the allowable maximum value $\mathbf{faf_{max}}$ **(**$\mathbf{faf \leq faf_{max}}$**).** If **"**$\mathbf{faf \leq faf_{max}}$**"** is not established, the process proceeds to step **S109**, where the fuel correction amount **faf** is restricted by the maximum value (maximum fuel correction amount) $\mathbf{faf_{max}}$**,** and then proceeds to step **S110**. If $\mathbf{faf \leq faf_{max}}$ at step **S108**, the process directly proceeds to step **S110**, determining that the fuel correction amount **faf** is within the allowable range.

**[0065]** At step **S110**, the ECU **30** determines whether or not the EGR correction amount **kegr** is equal to or greater than the allowable minimum value $\mathbf{kegr_{min}}$ **(**$\mathbf{kegr_{min} \leq kegr}$**).** If **"**$\mathbf{kegr_{min} \leq keger}$**"** is not established, the process proceeds to step **S111**, where the EGR correction amount **kegr** is restricted by the minimum value (minimum EGR correction amount) $\mathbf{kegr_{min}}$. If $\mathbf{kegr_{min} \leq kegr}$ at step **S110**, the process proceeds to step **S112**, where the ECU **30** determines whether or not the EGR correction amount **kegr** is equal to or less than the allowable maximum value $\mathbf{kegr_{max}}$ **(**$\mathbf{kegr \leq kegr_{max}}$**).** If "$\mathbf{kegr \leq kegr_{max}}$**"** is not established, the process proceeds to step **S113**, where the EGR correction amount **kegr** is restricted by the maximum value (maximum EGR correction amount) $\mathbf{kegr_{max}}$.

**[0066]** Thus, in this example, where the combustion control is executed in the manner described above, the following effects (a) to (c) are obtained.

(a) The torque variation **dln** in the engine **1** is approximated to the target value **din|v|** by increasing or decreasing both the fuel injection amount and the EGR amount. This enables prompt and reliable approximation of the torque variation **dln** to the target value **dln|v|.**

(b) The target value **dln|v|** can be located in an area of the EGR amount in which the torque variation **dln** does not change excessively with the change in the EGR amount by increasing or decreasing the fuel injection amount. This prevents the torque variation **dln** from greatly displacing on the increase side with respect to the target value **dln|v|,** and thus prevents a reduction of the drivability due to such a great displacement of the torque variation **dln** on the increase side with respect to the target value **dln|v|.**

(C) In "stratified burning", the change in the $NO_x$ emission amount with the change in the EGR amount is small. Accordingly, the $NO_x$ emission amount will not excessively increase with the shift from point **P** to point **Q** in Figure **10**. Emission is therefore prevented from being worsened.

(Second example)

**[0067]** The second example will be described with reference to the relevant drawings. This example is different from the first example only in the control methods for the fuel injection amount control and the EGR amount control. The construction of this example is the same as that of the first example shown in Figures **3** and **4**.

**[0068]** Figure **11** shows a processing routine for executing the fuel injection amount control and the EGR amount control in this example. This routine is executed at an occasion of angle interruption for each predetermined crank angle.

**[0069]** In the illustrated processing routine, at step **S201**, the ECU **30** calculates the torque variation **dln** of the engine **1** as in step **S101** in the first example. Then, at step **S202**, the ECU **30** determines whether or not the calculated torque

variation **dln** is larger than a value obtained by adding a predetermined value **Ch1** to the target value **dln|v| (dln|v| + Ch1)**. If **dln > dln|v| + Ch1,** i.e., the torque variation **dln** is in a range **A** shown in Figure **12**, the process proceeds to step **S203**.

**[0070]** At step **S203**, the ECU **30** corrects the fuel injection amount incrementally by adding the fuel correction amount **faf**. Then, at step **S204**, the ECU **30** determines whether or not the torque variation **dln** is larger than a value obtained by adding a predetermined value **Ch2** to the target value **dln|v| (dln|v| + Ch2)**. The predetermined value **Ch2** is set at a value larger than the predetermined value **Ch1**. If **dln > dln|v| + Ch2**, i.e., the torque variation **dln** is in a range **D** shown in Figure **12**, the process proceeds to step **S205**. At step **S205**, the ECU **30** decreases an EGR correction amount **kegr** to decrease the EGR amount, and the process proceeds to step **S206**. If **"dln > dln|v| + Ch2"** is not established at step **204**, i.e., the torque variation **dln** is in a range **E** shown in Figure **12**, the process directly proceeds to step **S206**.

**[0071]** In the above fuel injection amount control and the EGR amount control, where the predetermined value **Ch2** is set larger than the predetermined value **Ch1**, when the torque variation **dln** exceeds the target value **dln|v|,** the fuel injection amount is first increased before the EGR amount is decreased. Accordingly, when the torque variation **dln** is slightly displaced from the target value **dln|v|** on the increase side as indicated by point **p** in Figure **13**, only the fuel injection amount is increased without decreasing the EGR amount, allowing point **p** to shift to point **q** and thus approximating the torque variation **dln** to the target value **dln|v|.** In this case, as shown in Figure **14**, since the EGR amount is not decreased, the $NO_x$ emission amount is not increased with the shift of point **p** to point **q,** preventing emission from worsening.

**[0072]** If **"dln > dln|v| + Ch1"** is not established at step **S202**, the process proceeds to step **S214**. At step **S214**, the ECU **30** determines whether or not the torque variation **dln** is smaller than a value obtained by subtracting a predetermined value **C11** from the target value **dln|v| (dln|v| - C11)**. If **"dln < dln|v| - C11"** is not established, i.e., the torque variation **dln** is in a range **B** shown in Figure **12**, the ECU **30** terminates this processing. If **dln < dln|v| - C11,** i.e., the torque variation **dln** is in a range **C** shown in Figure **12**, the process proceeds to step **S215**.

**[0073]** At step **S215**, the ECU **30** corrects the fuel injection amount decrementally by decreasing the fuel correction amount **faf**. Then, the process proceeds to step **S216**, where the ECU **30** determines whether or not the torque variation **dln** is smaller than a value obtained by subtracting a predetermined value **C12** from the target value **dln|v| (dln|v| - C12)**. The predetermined value **C12** is set at a value larger than the predetermined value **C11**. If **dln < dln|v| - C12**, i.e., the torque variation **dln** is in a range **F** shown in Figure **12**, the process proceeds to step **S217**. At step **S217**, the ECU **30** increases the EGR amount by increasing the EGR correction amount **kegr**, and the process proceeds to step **S206**. If **"dln < dln|v| - C12"** is not established at step **S216**, i.e., the torque variation **dln** is in a range **G** shown in Figure **12**, the process directly proceeds to step **S206**.

**[0074]** In the above fuel injection amount control and the EGR amount control, where the predetermined value **C12** is set larger than the predetermined value **C11**, when the torque variation **dln** becomes less than the target value **dln|v|,** the fuel injection amount is first decreased before the EGR amount is increased. Accordingly, when the torque variation **dln** is slightly displaced from the target value **dln|v|** on the decrease side as indicated by point **s** in Figure **13**, only the fuel injection amount is decreased without increasing the EGR amount, allowing point **s** to shift to point **t** and thus approximating the torque variation **dln** to the target value **dln|v|.** In this case, as shown in Figure **14**, since the fuel injection amount is decreased, not increasing the EGR amount, with the shift of point **s** to point **t**, fuel consumption can be reduced.

**[0075]** Steps **S206** to **S213** are the same as steps **S106** to **S113** in the first example. The description of these steps is therefore omitted here.

**[0076]** Thus, in this example, where the combustion control is executed in the manner described above, the following effects (d) to (f) are obtained, in addition to the effects described in the first example.

(d) The predetermined value **Ch2** is set larger than the predetermined value **Ch1**, so that when the torque variation **dln** exceeds the target value **dln|v|,** the fuel injection amount is first increased before the EGR amount is decreased. Under this control, when the torque variation **dln** is slightly displaced from the target value **dln|v|** on the increase side, only the fuel injection amount is increased without decreasing the EGR amount so as to approximate the torque variation **dln** to the target value **dln|v|.** Since the EGR amount is not decreased, the $NO_x$ emission amount is prevented from increasing, and thus emission is prevented from worsening.

(e) The predetermined value **C12** is set larger than the predetermined value **C11**, so that when the torque variation **dln** becomes less than the target value **dln|v|,** the fuel injection amount is first decreased before the EGR amount is increased. Under this control, when the torque variation **dln** is slightly displaced from the target value **dln|v|** on the decrease side, only the fuel injection amount is decreased without increasing the EGR amount so as to approximate the torque variation **dln** to the target value **dln|v|.** Since the fuel injection amount is decreased without increasing the EGR amount, fuel consumption can be reduced.

(f) The EGR mechanism **51** generates a response delay in which the change in the EGR amount in response to a change in the opening of the EGR valve **53** is delayed. In this example, when the torque variation **dln** is slightly displaced from the target value **dln|v|,** only the fuel injection amount is increased or decreased as described above. This prevents the EGR valve **53** from excessively responding to a slight displacement of the torque variation **dln** from the target value **dln|v|** on the increase or decrease side. Thus, in this example, the EGR amount is prevented from becoming an inappropriate value due to the response delay of the change in the EGR amount in response to a change in the opening of the EGR valve **53**.

(Third example)

**[0077]** The third example will be described with the relevant drawings. This example is different from the first and second examples only in the control methods for the fuel injection amount control and the EGR amount control. The construction of this example is the same as that of the first example shown in Figures **3** and **4**.

**[0078]** The ECU **30** of this example stores a learning map shown in Figure **16** and a basic fuel injection amount map shown in Figure **17** in the RAM **32** and the ROM **33**, respectively. The learning map has a plurality of learning areas **noarea** for the fuel correction amount **faf** and the EGR correction amount **kegr**, which are allocated based on the number of revolutions of the engine and the fuel injection amount. The basic fuel injection amount map has values of the basic fuel injection amount registered in correspondence with the opening of the accelerator. The actual fuel injection amount is determined by correcting the basic fuel injection amount using the fuel correction amount **faf**.

**[0079]** As described in the first example in detail, the fuel correction amount **faf** and the EGR correction amount **kegr** are changed so that the torque variation **dln** is approximated to the target value **dln|v|.** In this example, the changed values of the fuel correction amount **faf** and the EGR correction amount **kegr** are learned in association with the corresponding driving range of the engine **1**, i.e., in association with the corresponding number of revolutions of the engine and fuel injection amount. Accordingly, when the engine **1** is being driven in a driving state within a certain learning area **noarea** shown in Figure **16** and the fuel correction amount **faf** is changed, the fuel injection amount may be increased as represented by the two-dot chain line **L2** in Figure **17**, with respect to the basic fuel injection amount represented by the solid line **L1**. Further, when the driving state of the engine **1** is changed so that the learning area **noarea** is shifted to an adjacent learning area **noarea** while the number of revolutions of the engine is fixed, the fuel correction amount **faf** is additionally changed with the shift of the learning area **noarea**. This may result in that the fuel injection amount is decreased as represented by the two-dot chain line **L3**, for example, with respect to the basic fuel injection amount represented by the solid line **L1**.

**[0080]** Accordingly, when the driving state of the engine **1** is changed so as to shift to another learning area **noarea**, if the value of the fuel correction amount **faf** changed in the preceding learning area **noarea** is still valid in the new learning area **noarea**, the fuel injection amount which changes according to the opening of the accelerator shifts as represented by the two-dot chain lines **L2** and **L3**. This indicates that as the opening of the accelerator increases, the fuel injection amount largely changes at the moment when the driving state shifts from one learning area **noarea** to another, resulting in generating a shock to the engine **1**.

**[0081]** Figure **15** shows a processing routine for preventing such a shock from being generated due to such a change in the fuel correction amount **faf**, where the learning area **noarea** is shifted, the fuel correction amount **faf** is initialized (e.g., it is set at "1" for multiplication correction and "0" for addition or subtraction correction).

**[0082]** More specifically, in the illustrated processing routine, at step **S301**, the ECU **30** determines whether or not the driving state has shifted from one learning area **noarea** to an adjacent learning area based on the fuel injection amount and the number of revolutions of the engine. If the driving state has shifted to an adjacent learning area **noarea**, the process proceeds to step **S302**, where the fuel correction amount faf is initialized. The process then proceeds to step **S303**. If it is determined that there is no shift to an adjacent learning area **noarea**, the process directly proceeds to step **S303**.

**[0083]** Steps **S303** to **S315** are the same as steps **S101** to **S113** in the first example. The description of these steps is therefore omitted here.

**[0084]** Thus, in this example, where the combustion control is executed in the manner described above, the following effect (g) is obtained, in addition to the effects described in the first example.

(g) When the driving state is shifted from one learning area **noarea** to an adjacent learning area, the fuel correction amount **faf** is initialized. This suppresses the fuel injection amount from being changed so greatly that a shock may be generated.

**[0085]** The above example may be modified as follows.

(1) In the above examples, the case where the engine **1** performs "stratified burning" was described. In a driving

range of the engine **1** in which the load is higher than that required to perform "stratified burning", "homogeneous lean burning" may be performed. To accomplish this, the engine **1** switches the burning method in accordance with the load, so as to perform either "stratified burning" or "homogeneous lean burning". During the "homogeneous lean burning", also, the fuel injection amount is increased or decreased by changing the fuel correction amount **faf**, so that the torque variation **dln** is approximated to the target value **dln|v|.** In this case, the maximum value $\mathbf{faf_{max}}$ of the fuel correction amount **faf** (maximum fuel correction amount) during the "stratified burning" is set at a value smaller than the maximum value $\mathbf{faf_{max}}$ of the fuel correction amount **faf** (maximum fuel correction amount) during the "homogeneous lean burning". This prevents misfiring due to an excessive fuel injection amount during the "stratified burning" in which a mixed gas including fuel at a high concentration.

(2) In the above examples, the torque variation **dln** was detected as an output variation of the engine **1**, and the fuel injection amount and the EGR amount were increased or decreased so as to approximate the torque variation **dln** to the target value **dln|v|.** The present invention is not limited to this construction. For example, the air fuel ratio which corresponds to the output variation of the engine **1** may be detected by an air fuel ratio sensor disposed in the engine **1**. The fuel injection amount and the EGR amount can be increased or decreased so that the actual air fuel ratio of the engine **1** detected by the air fuel ratio sensor is approximated to an air fuel ratio serving like the above target value **dln|v|** (target air fuel ratio).

(3) In place of detecting the torque variation **dln**, a cylinder internal pressure sensor may be provided for detecting the pressure in the combustion chamber **5**, so as to detect the time at which the cylinder internal pressure is maximum which changes in correspondence with the output variation of the engine **1**. The fuel injection amount and the EGR amount can be increased or decreased so that the actual cylinder internal pressure maximum time is approximated to a cylinder internal pressure maximum time serving like the above target value **dln|v|** (target cylinder internal pressure maximum time).

(4) A combustion pressure which changes in correspondence with the output variation of the engine **1** may be detected by the cylinder internal pressure sensor. The fuel injection amount and the EGR amount can be increased or decreased so that the actual combustion pressure is approximated to a combustion pressure serving like the above target value **dln|v|** (target combustion pressure).

(5) In place of detecting the torque variation **dln**, the rotational speed of the crank shaft which changes in correspondence with the output variation of the engine **1** may be detected. The fuel injection amount and the EGR amount can be increased or decreased so that the detected rotational speed is approximated to a rotational speed of the crank shaft serving like the above target value **dln|v|** (target rotational speed).

(6) In the second example, the fuel correction amount **faf** may be initialized when the driving state is shifted to another learning area **noarea**, as in the third example. In this case, both effects provided by the second and third examples can be obtained.

**[0086]** In the embodiment according to the invention, the combustion control device of the internal combustion engine according to the present invention is applied to a car engine performing "lean burning". This embodiment will be described in detail with reference to the relevant drawings. This embodiment is different from the first example only in the control methods for the fuel injection amount control and the EGR amount control. The construction of this embodiment is the same as that of the first example shown in Figures **3** and 4.

**[0087]** Referring to Figures **18** and **19**, the fuel injection amount control and the EGR amount control by the combustion control device of this embodiment will be described. Figures **18** and **19** show a processing routine for the fuel injection amount control and the EGR amount control executed by the ECU **30** at an occasion of angle interruption for each predetermined crank angle.

**[0088]** In the illustrated processing routine, at step **S401**, the ECU **30** subtracts "1" from a post EGR amount change counter **cegr**. The post EGR amount change counter **cegr** is decreased by "1" whenever a certain time passes (a certain angle is passed) after the preceding change of the EGR amount. The initial value of the post EGR amount change counter **cegr** is a predetermined value **Cc**, which will be described hereinafter. The predetermined value **Cc** is determined so that the EGR amount is not changed excessively.

**[0089]** At step **S402**, the ECU **30** determines whether or not the post EGR amount change counter **cegr** is equal to or greater than "0". If the post EGR amount change counter **cegr** is less than "0", the process proceeds to step **S403**. After the post EGR amount change counter **cegr** is set at "0" at step **S403**, the process proceeds to step **S404**. If the post EGR amount change counter **cegr** is equal to or greater than "0" at step **S402**, the process directly proceeds to step **S404**.

**[0090]** AT step **S404**, the ECU **30** calculates the torque variation **dln** of the entire engine **1** based on output pulses from the top dead center sensor **27** and the crank angle sensor **28**. The torque variation **dln** is calculated in accordance with expressions (1) to (3) above.

**[0091]** At step **S405**, the ECU **30** determines whether or not the calculated torque variation **dln** is larger than a value obtained by adding the predetermined value **C1** to the target value **dln|v| (dln|v| + C1)**. If **dln > dln|v| + C1,** i.e., the torque variation **dln** is in the range **A** shown in Figure **7**, the process proceeds to step **S406**. If **"dln > dln|v| + C1"** is not established, the process proceeds to step **S411** (Figure **19**).

**[0092]** Step **S406** and the subsequent steps in Figure **18** represent a portion of the processing routine for controlling the incremental correction of the fuel injection amount and the decremental correction of the EGR amount. Step **S411** and the subsequent steps in Figure **19** represent a portion of the processing routine for controlling the decremental correction of the fuel injection amount and the incremental correction of the EGR amount.

**[0093]** When the process proceeds to step **S406** based on the determination at step **S405**, the ECU **30** sets a value obtained by adding a predetermined value **Cf** to the fuel correction amount **faf** used in the preceding correction of the combustion injection amount **(faf + Cf)** as a new fuel correction amount **faf**. That is, the fuel injection amount is incrementally corrected at step **S406**. The process proceeds to step **S407**, where the ECU **30** determines whether or not the newly set fuel correction amount **faf** is equal to or less than the maximum fuel correction determination value $\mathbf{faf_{max}}$.

**[0094]** When the process proceeds to step **S411** based on the determination at step **S405**, the ECU **30** determines whether or not the torque variation **dln** is smaller than a value obtained by subtracting the predetermined value **C1** from the target value **dln|v| (dln|v| - C1)**. If **"dln < dln|v| - C1"** is not established, i.e., the torque variation **dln** is in the range **B** shown in Figure **7**, the ECU **30** terminates this processing routine. If **dln < dln|v| - C1,** i.e., the torque variation **dln** is in the range **C**, the process proceeds to step **S412**.

**[0095]** At step **S412**, the ECU **30** sets a value obtained by subtracting the predetermined value **Cf** from the fuel correction amount **faf** used in the preceding correction of the combustion injection amount **(faf - Cf)** as a new fuel correction amount **faf**. That is, the fuel injection amount is decrementally corrected at step **S412.** The process proceeds to step **S413**, where the ECU **30** determines whether or not the newly set fuel correction amount **faf** is equal to or greater than the minimum fuel correction determination value $\mathbf{faf_{min}}$.

**[0096]** The maximum fuel correction determination value $\mathbf{faf_{max}}$ and the minimum fuel correction determination value $\mathbf{faf_{min}}$ are calculated in the following manner. That is, the fuel correction amount **faf** is set at such a value that the fuel injection amount is not changed when it is corrected with the value (e.g., "1" for multiplication correction and "0" for addition or subtraction correction), and the fuel injection amount from the fuel injection valve **11** in the case of using this value is measured. At this time, the resultant fuel injection amount from the fuel injection value **11** is larger or smaller than a theoretical amount which should otherwise be injected, due to a design size tolerance and the like. The fuel correction amount **faf** required to obtain by fuel injection amount correction the same fuel injection amount as that obtained when the fuel injection amount is increased most greatly from the theoretical value due to a size tolerance and the like, is set as the maximum fuel correction determination value $\mathbf{faf_{max}}$. Likewise, the fuel correction amount **faf** required to obtain by fuel injection amount correction the same fuel injection amount as that obtained when the fuel injection amount is decreased most greatly from the theoretical value due to a size tolerance and the like, is set as the minimum fuel correction determination value $\mathbf{faf_{min}}$.

**[0097]** By the above setting of the maximum fuel correction determination value $\mathbf{faf_{max}}$ and the minimum fuel correction determination value $\mathbf{faf_{min}}$, it is ensured that the fuel injection amount from the fuel injection valve **11** falls within a range of increase and decrease due to a size tolerance and the like if $\mathbf{"faf \leq faf_{max}"}$ is determined at step **S407** or $\mathbf{"faf \geq faf_{min}"}$ is determined at step **S413**.

**[0098]** Thus, when the above determination is made, it is considered that the torque variation **dln** of the engine **1** may be in the range **A** or **C** (Figure **7**) which is away from the target value **dln|v|** presumably because of an increase or a decrease (variation) of the fuel injection amount generated due to the design size tolerance of the fuel injection valve and the like. In other words, the torque variation **dln** may be displaced from the target value **dln|v|** when the fuel injection amount is increased or decreased from a required amount. For this reason, if $\mathbf{"faf \leq faf_{max}"}$ is determined at step **S407** or $\mathbf{"faf \geq faf_{min}"}$ is determined at step **S413**, the processing routine is terminated without changing the EGR amount.

**[0099]** At step **S407,** if it is determined that $\mathbf{"faf \leq faf_{max}"}$ is not established, this means that the fuel injection amount from the fuel injection valve **11** is displaced on the increase side from the range of increase and decrease due to a size tolerance and the like. In this case, the process proceeds to step **S408**, where the ECU **30** determines whether or not the post EGR amount change counter **cegr** is "0", that is, whether or not a predetermined time has passed after the preceding EGR amount change, so as to avoid an excessive change of the EGR amount. If **"cegr** = 0" is not established, the processing routine is terminated. If **cegr** = 0, the process proceeds to step **S409**.

**[0100]** At step **S409**, the ECU **30** sets a value obtained by subtracting a predetermined value **Ce** from the EGR correction amount **kegr** used in the preceding EGR amount correction **(kegr - Ce)** as a new EGR correction amount **kegr**. In other words, the EGR amount is decrementally corrected at step **S409**. The process proceeds to step **S410**, where the ECU **30** sets the post EGR amount change counter **cegr** at the predetermined value **Cc**. The predetermined

value **Cc** is set so that the EGR amount is not changed excessively as described above.

**[0101]** At step **S413**, if it is determined that **"faf** $\geq$ **$faf_{min}$"** is not established, this means that the fuel injection amount from the fuel injection valve **11** is displaced on the decrease side from the range of increase and decrease due to a size tolerance and the like. In this case, the process proceeds to step **S414**, where the ECU **30** determines whether or not the post EGR amount change counter **cegr** is "0", that is, whether or not a predetermined time has passed after the preceding EGR amount change, as in step **S408** described above. If "**cegr** = 0" is not established, the processing routine is terminated. If **cegr** = 0, the process proceeds to step **S415.**

**[0102]** At step **S415**, the ECU **30** sets a value obtained by adding the predetermined value **Ce** to the EGR correction amount **kegr** used in the preceding EGR amount correction **(kegr + Ce)** as a new EGR correction amount **kegr**. In other words, the EGR amount is incrementally corrected at step **S415**. The process proceeds to step **S416**, where the ECU **30** sets the post EGR amount change counter **cegr** at the predetermined value **Cc**, as in step **S410** described above.

**[0103]** In this embodiment described above for controlling the correction of the fuel injection amount and the EGR amount, the following effect (a) is obtained.

(a) In the above processing routine, in increasing or decreasing the fuel injection amount so that the torque variation **dln** of the engine **1** is approximated to the target value **dln|v|,** when the fuel injection amount falls within the range of increase and decrease due to the size tolerance of the fuel injection valve **11** and the like, the EGR amount is not changed. Therefore, when the fuel injection amount decreases below a required amount due to a size tolerance and the like, increasing the output variation **dln** of the engine **1 ("dln > dln|v| + C1"),** the EGR amount will not be decreased unlike the conventional case where it is decreased to approximate the output variation **dln** to the target value **dln|v|.** This ensures prevention of the problem of worsening emission in the engine **1** performing "lean burning", which otherwise occurs because the ECR amount is decreased when the fuel injection amount decreases below a required amount due to the tolerance and the like described above.

**[0104]** This embodiment may be modified as follows.

(1) In this embodiment, in the case where the fuel correction amount **faf** exceeds a fuel correction amount **fafM1** which is larger than the maximum value **$faf_{max}$,** a new EGR correction amount may be set by subtracting a predetermined value **CeB1**, which is larger than the predetermined value **Ce**, from the EGR correction amount **kegr** obtained by EGR correction performed before the fuel correction amount **faf** becomes larger than the correction amount **fafM1**. In this case, as the fuel injection amount after the correction is farther displaced from the range of increase and decrease of the fuel injection amount due to the size tolerance of the fuel injection valve **11** and the like, the decrease of the EGR amount is larger. As a result, the output variation of the engine **1** can be reliably suppressed by decreasing the EGR amount even when the corrected fuel injection amount is widely displaced on the increase side from the range of increase and decrease of the fuel injection amount due to the size tolerance and the like described above.

(2) In the above paragraph (1), a plurality of (e.g., three) correction amounts **fafM1** to **fafM3** which are larger than the maximum value **$faf_{max}$** may be sequentially set, and a plurality of (e.g., three) predetermined values **CeB1** to **CeB3** used for the setting of the EGR correction amount may be set to be sequentially larger in correspondence with the correction amounts **fafM1** to **fafM3**. In this case, also, as the fuel injection amount after the correction is farther displaced from the range of increase and decrease of the fuel injection amount due to the size tolerance of the fuel injection valve **11** and the like, the decrease of the EGR amount is larger. Thus, substantially the same effect as that described in paragraph (1) above can be obtained.

(3) In this embodiment, in the case where the fuel correction amount **faf** becomes smaller than a correction amount **fafm1** which is smaller than the minimum value **$faf_{min}$**, a new EGR correction value may be set by adding a predetermined value **Ceb1**, which is larger than the predetermined value **Ce**, to the EGR correction amount **kegr** obtained by EGR correction performed before the fuel correction amount **faf** becomes smaller than the correction amount **fafm1**. As a result, the emission worsening can be reliably prevented by the increase of the EGR amount even when the corrected fuel injection amount is widely displaced on the increase side from the range of increase and decrease of the fuel injection amount due to a size tolerance and the like.

(4) In the above paragraph (3),a plurality of (e.g., three) correction amounts **fafm1** to **fafm3** which are smaller than the minimum value **$faf_{min}$** may be sequentially set, and a plurality of (e.g., three) predetermined values **Ceb1** to **Ceb3** used for the setting of the EGR correction amount may be set to be sequentially larger in correspondence with the correction amounts **fafm1** to **fafm3**. In this case, also, as the fuel injection amount after the correction is farther displaced from the range of increase and decrease of the fuel injection amount due to the size tolerance of

the fuel injection valve **11** and the like, the increase of the EGR amount is made larger. Thus, substantially the same effect as that described in paragraph (3) above can be obtained.

(5) In this embodiment, the minimum fuel correction determination value **fafmin** and the maximum fuel correction determination value **fafmax** were set based on the size tolerance of the fuel system such as the fuel injection valve **11**. The present invention is not limited to this setting. For example, the actual air fuel ratio may be measured using an air fuel ratio sensor, to obtain the minimum and maximum of a variation of the air fuel ratio. The fuel correction amounts **faf** required, by fuel injection amount correction, to obtain the same fuel injection amounts as those obtained when the minimum and maximum of the air fuel ratio are used, may be set as the minimum fuel correction determination value $\mathbf{faf_{min}}$ and the maximum fuel correction determination value $\mathbf{faf_{max}}$, respectively. The thus-obtained minimum fuel correction determination value $\mathbf{faf_{min}}$ and maximum fuel correction determination value $\mathbf{faf_{max}}$ are values which consider not only the size tolerance of the fuel system such as the fuel injection valve **11** but also the size tolerance of the intake system such as the throttle valve.

(6) In general, the fuel correction amount **faf**, the EGR amount, and the $NO_x$ emission amount have the relationship shown in Figure **20**, and the fuel correction amount **faf**, the EGR amount, and the torque variation have the relationship shown in Figure **21**. Using these relationships, the minimum and maximum values of a level of the fuel correction amount **faf** that satisfies the torque variation and the $NO_x$ emission amount may be determined by experiment, so that the determined minimum and maximum values are set as the minimum fuel correction determination value $\mathbf{faf_{min}}$ and the maximum fuel correction determination value $\mathbf{faf_{max}}$.

(7) In this embodiment, for the output variation of the engine **1**, the air fuel ratio which changes in correspondence with the output variation may be detected by an air fuel ratio sensor disposed in the engine **1**. In this case, the fuel injection amount can be increased or decreased so that the actual air fuel ratio of the engine **1** detected by the air fuel ratio sensor is approximated to an air fuel ratio serving like the target value **dln|v|** (target air fuel ratio).

(8) In place of detecting the torque variation **dln**, a cylinder internal pressure sensor may be provided for detecting the pressure in the combustion chamber **5**, so as to detect the time at which the cylinder internal pressure is maximum, which changes in correspondence with the output variation of the engine **1**. The fuel injection amount can be increased or decreased so that the actual cylinder internal pressure maximum time is approximated to a cylinder internal pressure maximum time serving like the above target value **dln|v|** (target cylinder internal pressure maximum time).

(9) In place of detecting the torque variation **dln**, the rotational speed of the crank shaft which changes in correspondence with the output variation of the engine **1** may be detected. The fuel injection amount can be increased or decreased so that the detected rotational speed is approximated to a rotational speed of the crank shaft serving like the above target value **dln|v|** (target rotational speed).

## INDUSTRIAL APPLICABILITY

**[0105]** Thus, according to the present invention, in the case where the output variation of the internal combustion engine is displaced from a target value, both the fuel injection amount and the exhaust gas recirculation amount are increased or decreased to approximate the output variation to the target value. This enables quick approximation of the output variation to the target value.

**[0106]** The fuel injection amount is decreased when the output variation of the internal combustion engine is smaller than the target value, and the fuel injection amount is increased when the output variation of the internal combustion engine is larger than the target value, so that the output variation is approximated to the target value.

**[0107]** The fuel injection amount increases or decreases from a required amount due to the size tolerances of the intake system and the fuel system of the internal combustion engine, for example. When the fuel injection amount is displaced on the increase side from a range of increase and decrease in which the fuel injection amount is increased or decreased due to a size tolerance and the like, the exhaust gas amount to be recirculated to the intake system of the internal combustion engine is decreased so as to approximate the output variation to a target value. This means that when the fuel injection amount is decreased from a required amount due to the tolerances, increasing the output variation of the internal combustion engine, the exhaust gas recirculation amount is not decreased to approximate the output variation to the target value. Moreover, the decrease of the exhaust gas recirculation amount is made larger as the fuel injection amount is farther displaced from the above range of increase and decrease on the increase side. Accordingly, even when the fuel injection amount is widely displaced from the range of increase and decrease of the fuel injection amount due to the size tolerances and the like, the output variation of the internal combustion engine can be reliably

suppressed.

**[0108]** Accordingly, in an internal combustion engine performing lean burning, when the fuel injection amount becomes smaller than a required amount due to the size tolerances of the intake system and the fuel system of the engine and the like, the exhaust gas to be recirculated will not be decreased, and thus emission is reliably prevented from worsening.

**[0109]** When the fuel injection amount is displaced on the decrease side from the range of increase and decrease of the fuel injection amount due to a size tolerance and the like, the increase amount of the exhaust gas to be recirculated is made larger as the fuel injection amount is farther displaced from the range of increase and decrease. Accordingly, in an internal combustion engine performing lean burning, even when the fuel injection amount is widely displaced on the increase side from the range of increase and decrease of the fuel injection amount due to a size tolerance and the like, emission is reliably prevented from worsening.

## Claims

**1.** A combustion control device for an internal combustion engine (1), comprising:

fuel injection means (11) for injecting fuel into a cylinder (#1 - #4) of the internal combustion engine (1);
exhaust gas recirculation means (51) for recirculating part of exhaust gas exhausted from an exhaust system (14) of the internal combustion engine (1) to an intake system (15) of the internal combustion engine (1);
output variation detection means (27, 28, 30) for detecting an output variation of the internal combustion engine (1); and
injection amount control means (30) for correcting a fuel injection amount (faf) injected by the fuel injection means (11) based on the output variation detected by the output variation detection means (27, 28, 30) so as to approximate the output variation to a target value (dln|v|); **characterized by**
recirculation amount control means (30) for correcting an exhaust gas amount (kegr) to be recirculated by the exhaust gas recirculation means (51) so as to approximate the output variation of the internal combustion engine (1) to the target value (dln|v|) when the fuel injection amount (faf) corrected by the injection amount control means (30) is displaced from a predetermined range of increase and decrease, wherein the recirculation amount control means (30) decreases the exhaust gas amount (kegr) to be recirculated when the fuel injection amount (faf) controlled by the injection amount control means (30) is displaced from a predetermined range of increase and decrease on the increase side, and wherein the recirculation amount control means (30) increases the exhaust gas amount (kegr) to be recirculated when the fuel injection amount (faf) controlled by the injection amount control means (30) is displaced from a predetermined range of increase and decrease on the decrease side.

**2.** A combustion control device for an internal combustion engine (1) according to claim 1, wherein the injection amount control means (30) corrects the fuel injection amount (faf) incrementally when the output variation of the internal combustion engine (1) is greater than the target value (dln|v).

**3.** A combustion control device for an internal combustion engine (1) according to claim 2, wherein the recirculation amount control means (30) makes larger a decrease of the exhaust gas amount (kegr) to be recirculated as the fuel injection amount (faf) controlled by the injection amount control means (30) is displaced farther from the range of increase and decrease on the increase side.

**4.** A combustion control device for an internal combustion engine (1) according to claim 1, wherein the injection amount control means (30) corrects the fuel injection amount (faf) decrementally when the output variation of the internal combustion engine (1) is smaller than the target value (dln|v).

**5.** A combustion control device for an internal combustion engine (1) according to claim 4, wherein the recirculation amount control means (30) makes larger an increase of the exhaust gas amount (kegr) to be recirculated as the fuel injection amount (faf) controlled by the injection amount control means (30) is displaced farther from the range of increase and decrease on the decrease side.

## Patentansprüche

**1.** Verbrennungssteuervorrichtung für eine Brennkraftmaschine (1), die Folgendes aufweist:

eine Kraftstoffeinspritzeinrichtung (11) zum Einspritzen von Kraftstoff in einen Zylinder (#1 - #4) der Brennkraftmaschine (1);
eine Abgasrückführungseinrichtung (51) zum Rückführen eines Teils des Abgases, das von einem Abgassystem (14) der Brennkraftmaschine (1) abgegeben ist, zu einem Einlasssystem (15) der Brennkraftmaschine (1) ;
eine Ausgabeveränderungserfassungseinrichtung (27, 28, 30) zum Erfassen einer Ausgabeveränderung der Brennkraftmaschine (1); und
eine Einspritzmengensteuereinrichtung (30) zum Korrigieren einer Kraftstoffeinspritzmenge (faf), die durch die Kraftstoffeinspritzeinrichtung (11) eingespritzt ist, basierend auf der Ausgabeveränderung, die durch die Ausgabeveränderungserfassungseinrichtung (27, 28, 30) erfasst ist, um die Ausgabeveränderung auf einen Sollwert (dln|v|) anzunähern;
**gekennzeichnet durch**
eine Rückführungsmengensteuereinrichtung (30) zum Korrigieren einer Abgasmenge (kegr), die **durch** die Abgasrückführungseinrichtung (51) zurückgeführt werden soll, um die Ausgabeveränderung der Brennkraftmaschine (1) auf den Sollwert (dln|v|) anzunähern, wenn die Kraftstoffeinspritzemenge (faf), die **durch** die Einspritzmengensteuereinrichtung (30) korrigiert ist, von einem vorbestimmten Bereich eines Anstiegs und einer Abnahme verschoben ist, wobei die Rückführungsmengensteuereinrichtung (30) die Abgasmenge (kegr), die zurückzuführen ist, verringert, wenn die Kraftstoffeinspritzmenge (faf), die **durch** die Einspritzmengensteuereinrichtung (30) gesteuert ist, von einem vorbestimmten Bereich eines Anstiegs und einer Abnahme zu der Anstiegsseite hin versetzt ist, und wobei die Rückführungsmengensteuereinrichtung (30) die Abgasmenge (kegr), die zurückzuführen ist, anhebt, wenn die Kraftstoffeinspritzmenge (faf), die **durch** die Einspritzmengensteuereinrichtung (30) gesteuert ist, von einem vorbestimmten Bereich eines Anstiegs und einer Abnahme zu der Abnahmeseite verschoben ist.

**2.** Verbrennungssteuervorrichtung für eine Brennkraftmaschine (1) nach Anspruch 1, wobei die Einspritzmengensteuereinrichtung (30) die Kraftstoffeinspritzmenge (faf) schrittweise korrigiert, wenn die Ausgabeveränderung der Brennkraftmaschine (19 größer als der Sollwert (dln|v|) ist.

**3.** Verbrennungssteuervorrichtung für eine Brennkraftmaschine (1) nach Anspruch 2, wobei die Rückführungsmengensteuereinrichtung (30) eine Abnahme der zurückzuführenden Abgasmenge (kegr) größer macht, wenn die Kraftstoffeinspritzmenge (faf), die durch die Einspritzmengensteuereinrichtung (30) gesteuert ist, von dem Bereich eines Anstiegs und einer Abnahme weiter auf die Anstiegsseite hin verschoben ist.

**4.** Verbrennungssteuervorrichtung für eine Brennkraftmaschine (1) nach Anspruch 1, wobei die Einspritzmengensteuereinrichtung (30) die Kraftstoffeinspritzmenge (faf) dekrementell korrigiert, wenn die Ausgabeveränderung der Brennkraftmaschine kleiner als der Sollwert (dln|v|) ist.

**5.** Verbrennungssteuervorrichtung für eine Brennkraftmaschine (1) nach Anspruch 4, wobei die Rückführungsmengensteuereinrichtung (30) einen Anstieg der zurückzuführenden Abgasmenge (kegr) größer macht, wenn die Kraftstoffeinspritzmenge (faf), die durch die Einspritzmengensteuereinrichtung (30) gesteuert ist, von dem Bereich eines Anstiegs und einer Abnahme weiter auf die Abnahmeseite hin verschoben ist.

**Revendications**

**1.** Dispositif de commande de la combustion pour un moteur à combustion interne (1), comprenant :

un moyen d'injection de carburant (11) pour injecter du carburant dans un cylindre (#1 - #4) du moteur à combustion interne (1) ;
un moyen de recirculation des gaz d'échappement (51) pour recirculer une partie des gaz d'échappement refoulés d'un système d'échappement (14) du moteur à combustion interne (1) vers un système d'admission (15) du moteur à combustion interne (1) ;
un moyen de détection d'une variation de sortie (27, 28, 30) pour détecter une variation de sortie du moteur à combustion interne (1) ; et
un moyen de commande d'une quantité d'injection (30) pour corriger une quantité d'injection de carburant (faf) injectée par le moyen d'injection de carburant (11) sur la base de la variation de sortie détectée par le moyen de détection d'une variation de sortie (27, 28, 30) de manière à approcher la variation de sortie d'une valeur cible (dln|v|); et **caractérisé par**
un moyen de commande d'une quantité de recirculation (30) pour corriger une quantité de gaz d'échappement

(kegr) à recirculer par le moyen de recirculation de gaz d'échappement (51) de manière à approcher la variation de sortie du moteur à combustion interne (1) de la valeur cible (dln|v|) lorsque la quantité d'injection de carburant (faf) corrigée par le moyen de commande de la quantité d'injection (30) est déplacée d'une plage prédéterminée d'augmentation et diminution, dans lequel le moyen de commande de la quantité de recirculation (30) diminue la quantité de gaz d'échappement (kegr) à recirculer lorsque la quantité d'injection de carburant (faf) commandée par le moyen de commande de la quantité d'injection (30) est déplacée d'une plage prédéterminée d'augmentation et de diminution côté augmentation, et dans lequel le moyen de commande de la quantité de recirculation (30) augmente la quantité de gaz d'échappement (kegr) à recirculer lorsque la quantité d'injection de carburant (faf) commandée par le moyen de commande de la quantité d'injection (30) est déplacé d'une plage prédéterminée d'augmentation et de diminution côté diminution.

**2.** Dispositif de commande de la combustion pour un moteur à combustion interne (1) selon la revendication 1, dans lequel le moyen de commande de la quantité d'injection (30) corrige la quantité d'injection de carburant (faf) de manière incrémentielle lorsque la variation de sortie du moteur à combustion interne (1) est supérieure à la valeur cible (dln|v|).

**3.** Dispositif de commande de la combustion pour un moteur à combustion interne (1) selon la revendication 2, dans lequel le moyen de commande de la quantité de recirculation (30) accroît une baisse de la quantité de gaz d'échappement (kegr) à recirculer à mesure que la quantité d'injection de carburant (faf) commandée par le moyen de commande de la quantité d'injection (3) est déplacée plus à l'écart de la plage d'augmentation et de diminution côté augmentation.

**4.** Dispositif de commande de la combustion pour un moteur à combustion interne (1) selon la revendication 1, dans lequel le moyen de commande de la quantité d'injection (30) corrige la quantité d'injection de carburant (faf) de manière décrémentielle lorsque la variation de sortie du moteur à combustion interne (1) est plus petite que la valeur cible (dln|v|).

**5.** Dispositif de commande de la combustion pour un moteur à combustion interne (1) selon la revendication 4, dans lequel le moyen de commande de la quantité de recirculation (30) accroît une augmentation de la quantité de gaz d'échappement (kegr) à recirculer à mesure que la quantité d'injection de carburant (faf) commandée par le moyen de commande de la quantité d'injection (30) est déplacé plus à l'écart de la plage d'augmentation et de diminution côté diminution.

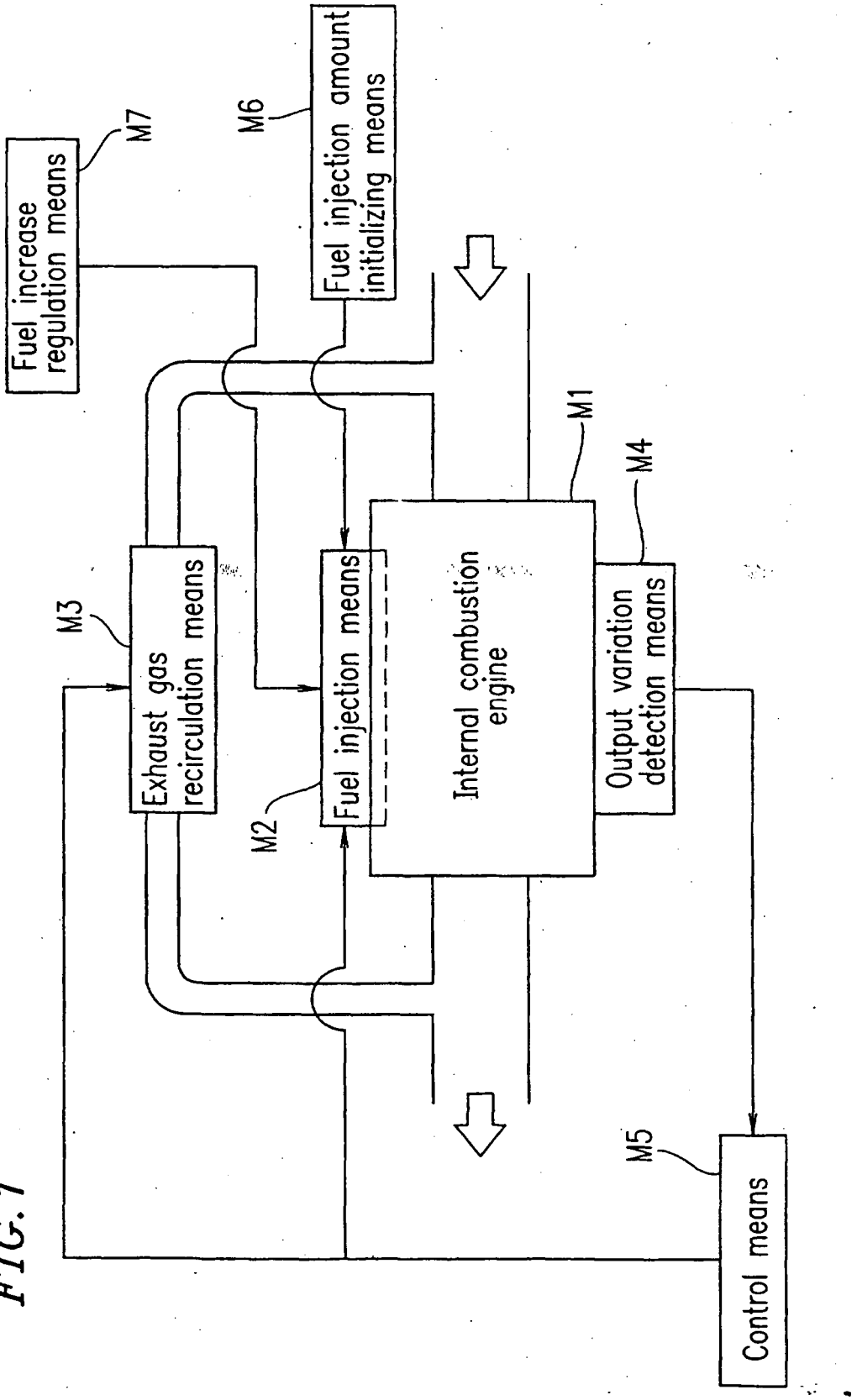

Fuel increase regulation means
M7
M6
Fuel injection amount initializing means
M1
M4
M3
Exhaust gas recirculation means
Fuel injection means
Internal combustion engine
Output variation detection means
M2
M5
Control means

FIG. 1

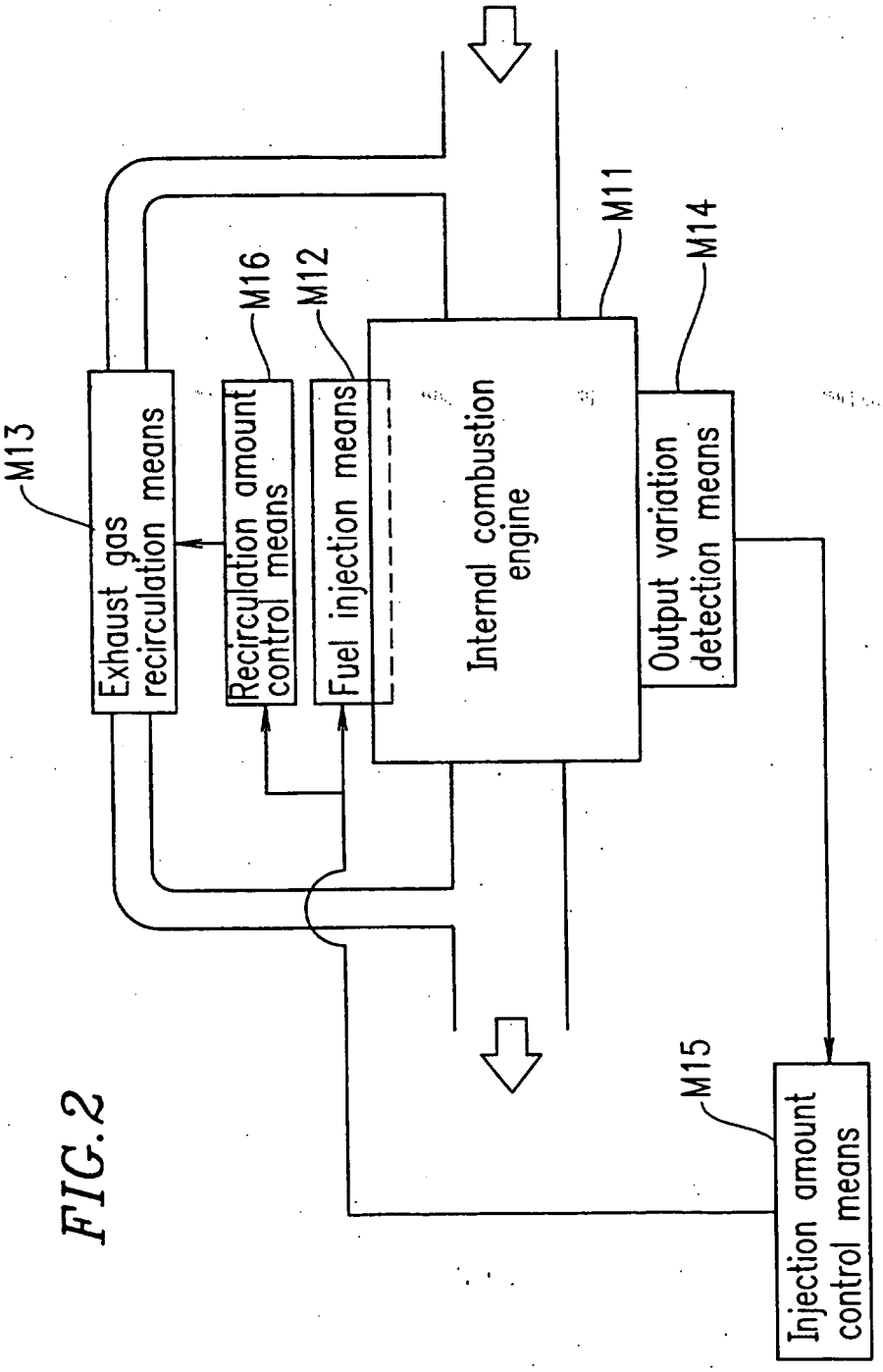

M13
Exhaust gas recirculation means
M16
Recirculation amount control means
M12
Fuel injection means
Internal combustion engine
M11
M14
Output variation detection means
M15
Injection amount control means

FIG. 2

*FIG. 3*

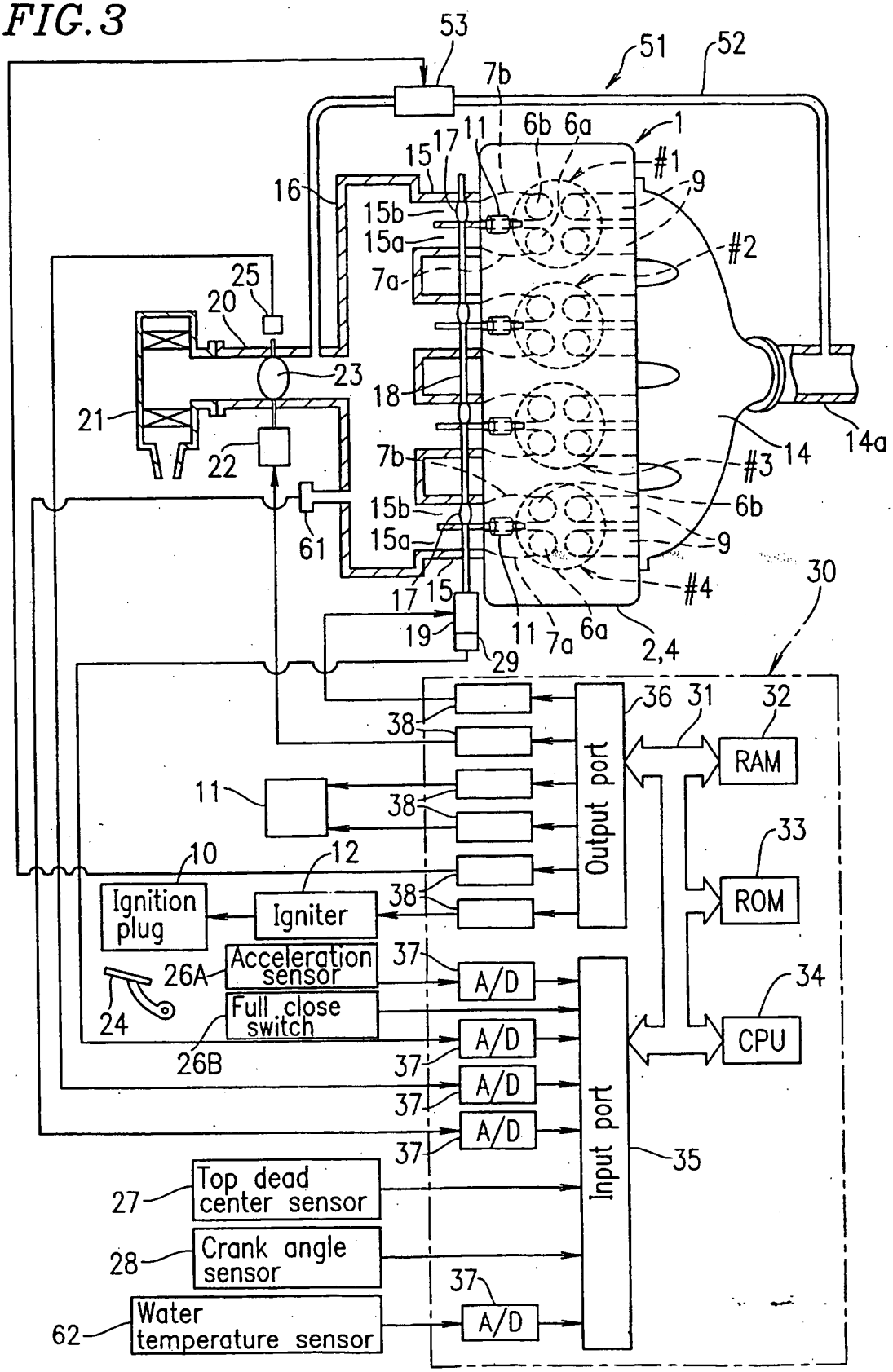

53
51
52
7b
11
6b
6a
1
15
17
#1
9
16
15b
15a
#2
7a
25
20
23
18
21
22
7b
#3
14
14a
15b
6b
61
15a
9
#4
30
17
15
19
11
7a
6a
2,4
29
36
31
32
38
RAM
Output port
11
38
33
10
12
ROM
Ignition plug
Igniter
38
37
Acceleration sensor
26A
A/D
34
24
Full close switch
CPU
A/D
26B
37
A/D
37
A/D
37
35
Input port
27
Top dead center sensor
28
Crank angle sensor
37
62
Water temperature sensor
A/D

*FIG. 4*

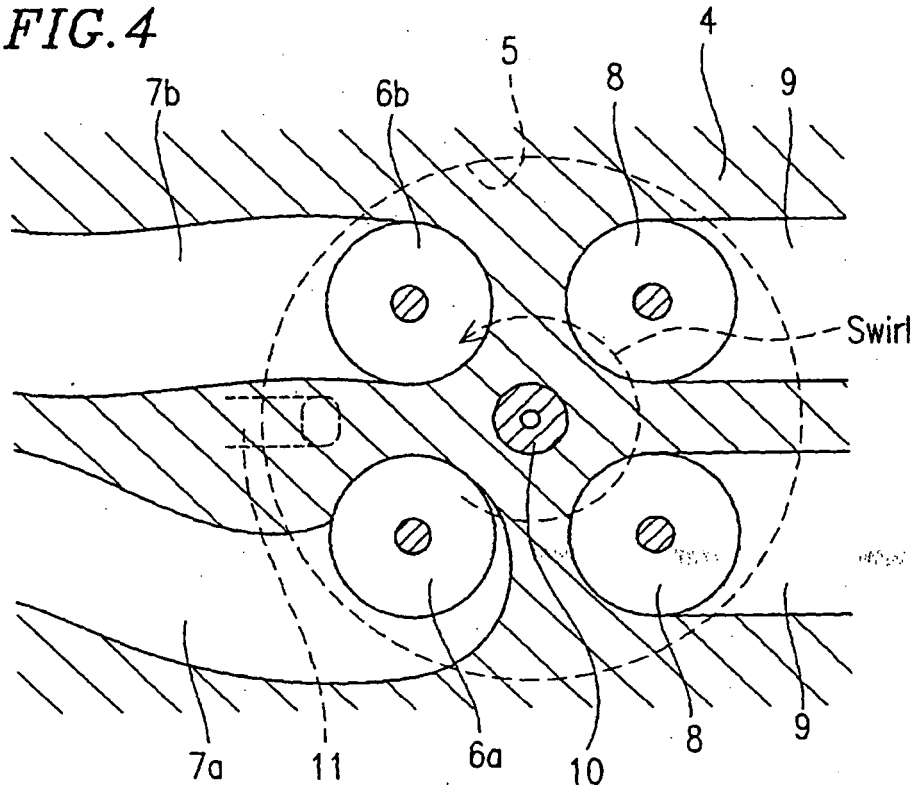


*FIG.5*

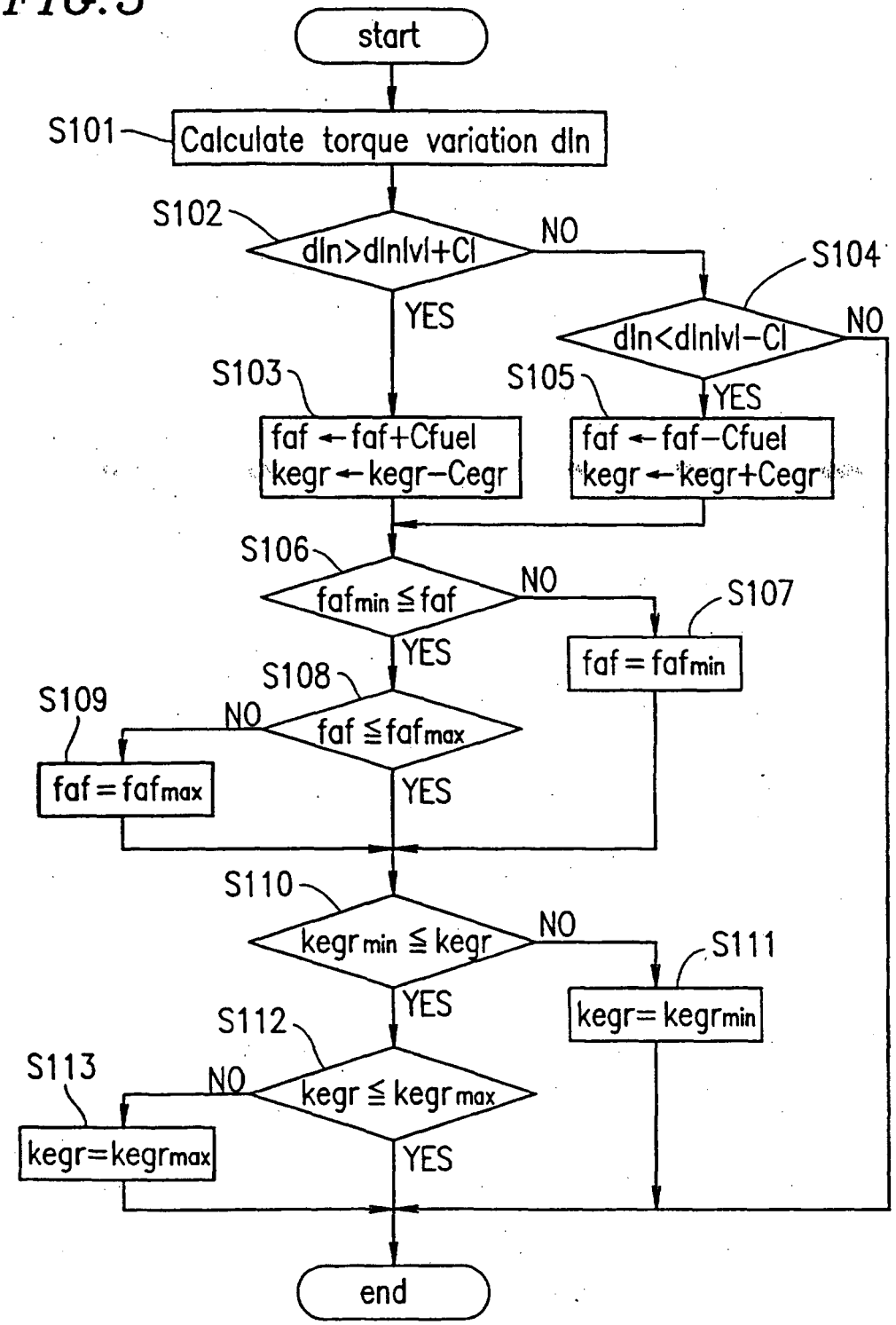

start
S101
Calculate torque variation dln
S102
dln>dlnlvl+Cl
NO
YES
S104
dln<dlnlvl-Cl
NO
YES
S103
faf ← faf+Cfuel
kegr ← kegr−Cegr
S105
faf ← faf−Cfuel
kegr ← kegr+Cegr
S106
fafmin ≦ faf
NO
YES
S107
faf = fafmin
S108
faf ≦ fafmax
NO
YES
S109
faf = fafmax
S110
kegr min ≦ kegr
NO
YES
S111
kegr= kegrmin
S112
kegr ≦ kegr max
NO
YES
S113
kegr=kegrmax
end

FIG. 6

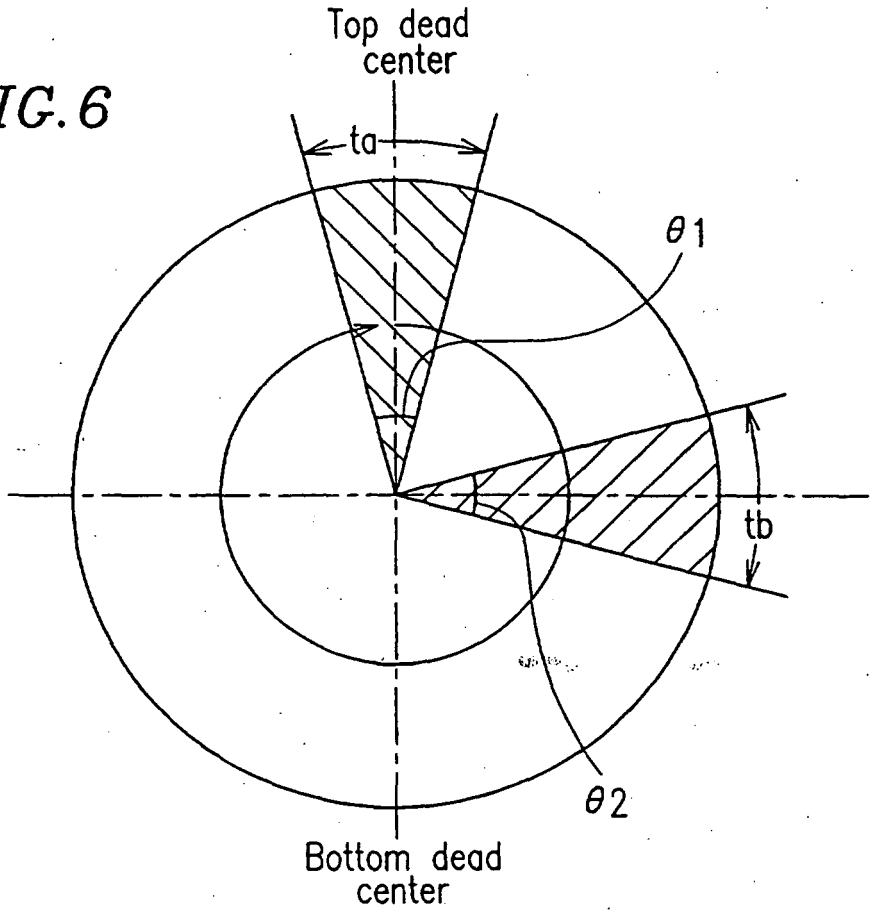

Top dead center
ta
θ1
tb
θ2
Bottom dead center

FIG. 7

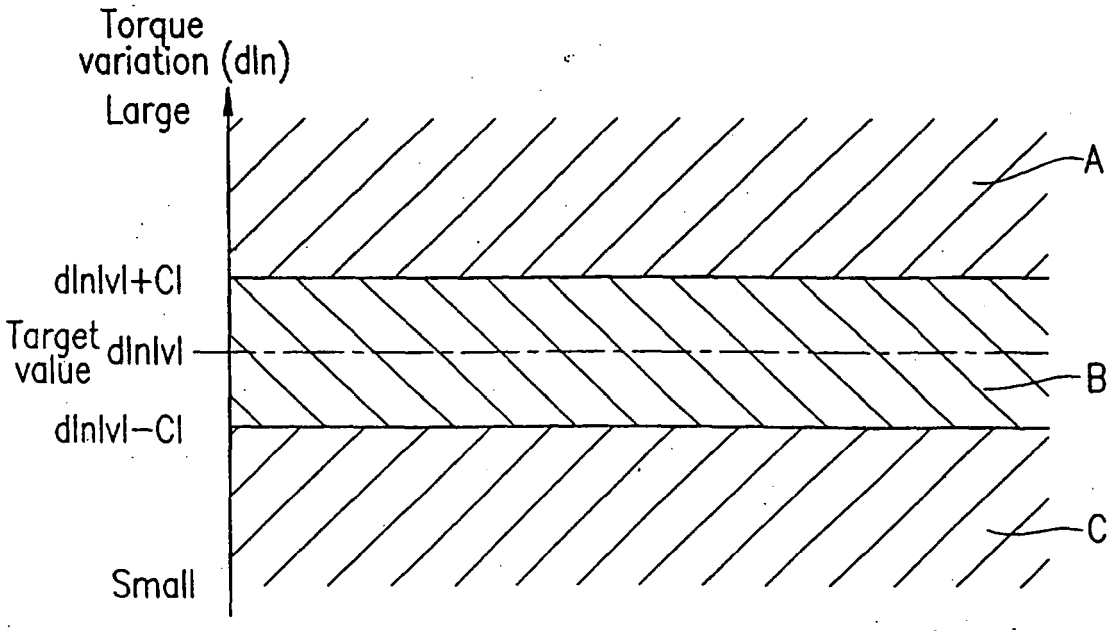

Torque variation (dIn)
Large
dInIvI+CI
Target value
dInIvI
dInIvI−CI
Small
A
B
C

*FIG. 8*

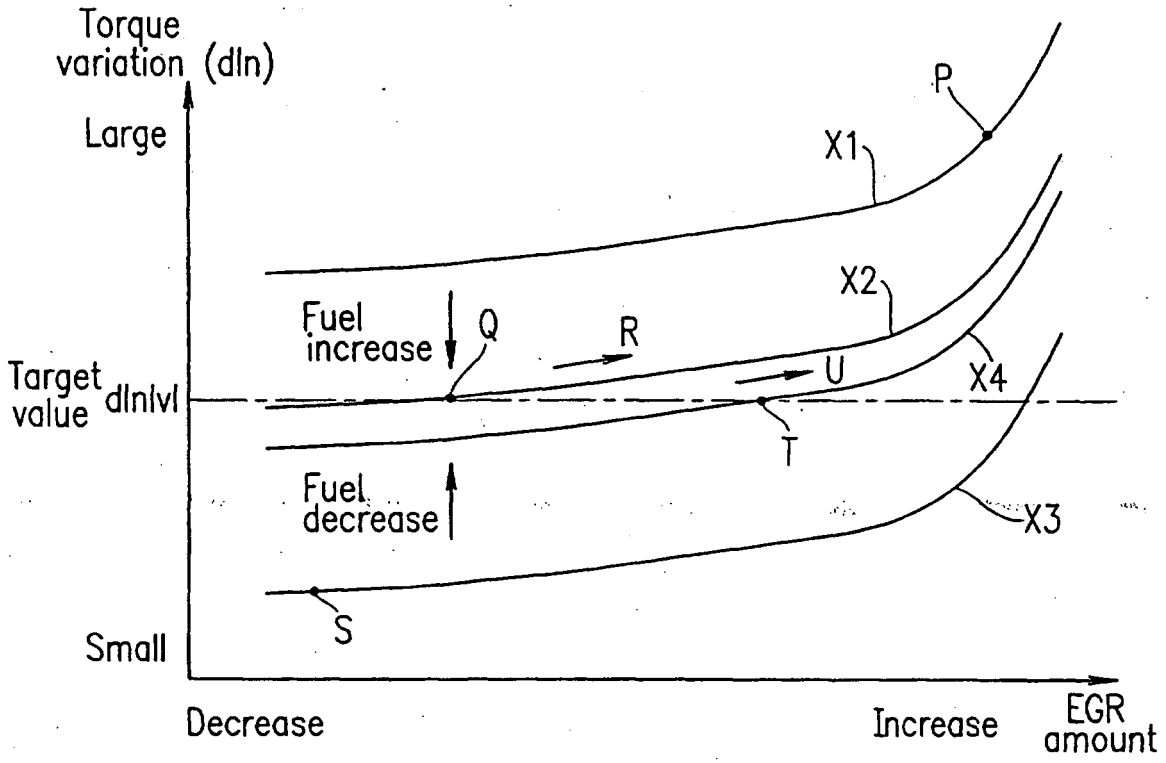

Torque variation (dIn)
Large
Small
Target value dInlvl
Fuel increase
Fuel decrease
P
X1
X2
X3
X4
Q
R
U
T
S
Decrease
Increase
EGR amount

*FIG. 9*

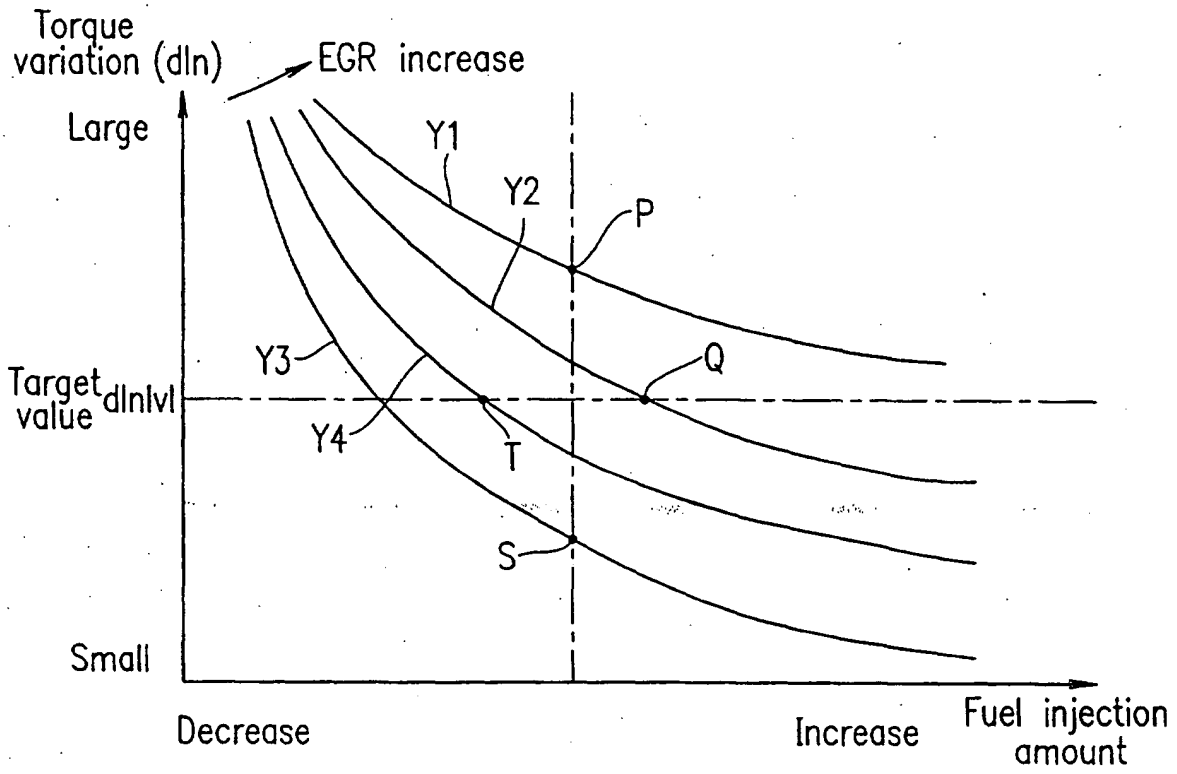

Torque variation (dIn)
EGR increase
Large
Y1
Y2
P
Y3
Q
Target value dInIvl
Y4
T
S
Small
Decrease
Increase
Fuel injection amount

*FIG. 10*

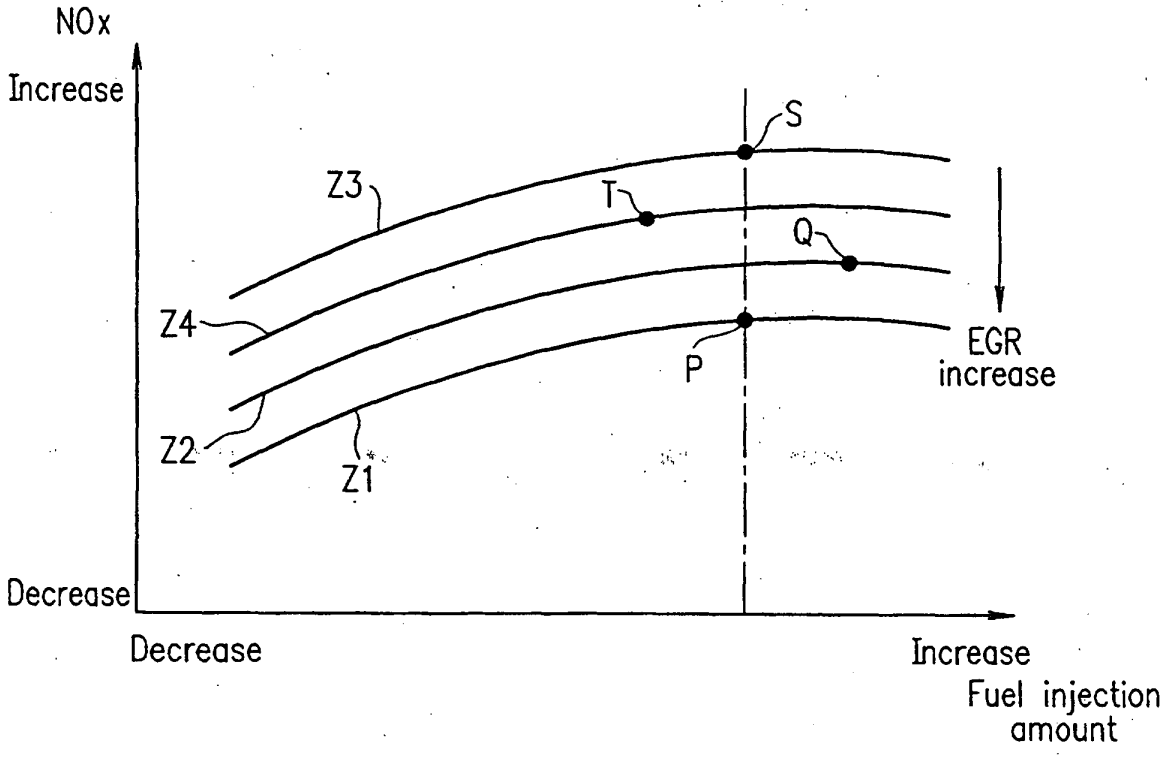

NOx
Increase
Decrease
Decrease
Increase
Fuel injection amount
EGR increase
S
T
Q
P
Z3
Z4
Z2
Z1

*FIG. 11*

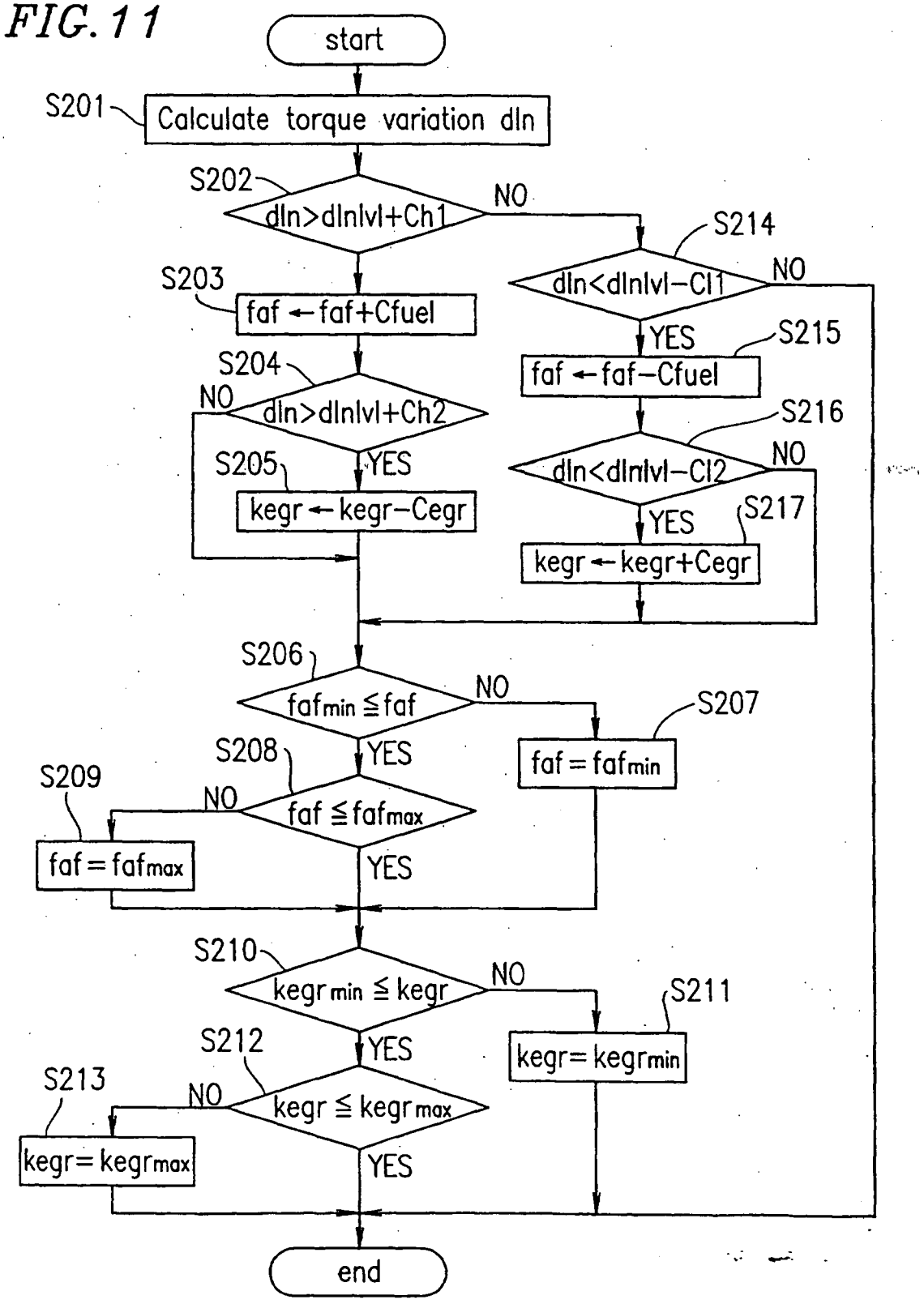

start
S201
Calculate torque variation dln
S202
dln>dlnlvl+Ch1
NO
S214
dln<dlnlvl−Cl1
NO
S203
faf ← faf+Cfuel
YES
S215
faf ← faf−Cfuel
S204
NO
dln>dlnlvl+Ch2
S216
dln<dlnlvl−Cl2
NO
S205
YES
kegr ← kegr−Cegr
YES
S217
kegr ← kegr+Cegr
S206
fafmin ≦ faf
NO
S207
faf = fafmin
S208
YES
S209
NO
faf ≦ fafmax
faf = fafmax
YES
S210
kegrmin ≦ kegr
NO
S211
kegr= kegrmin
S212
YES
S213
NO
kegr ≦ kegrmax
kegr= kegrmax
YES
end

*FIG. 12*

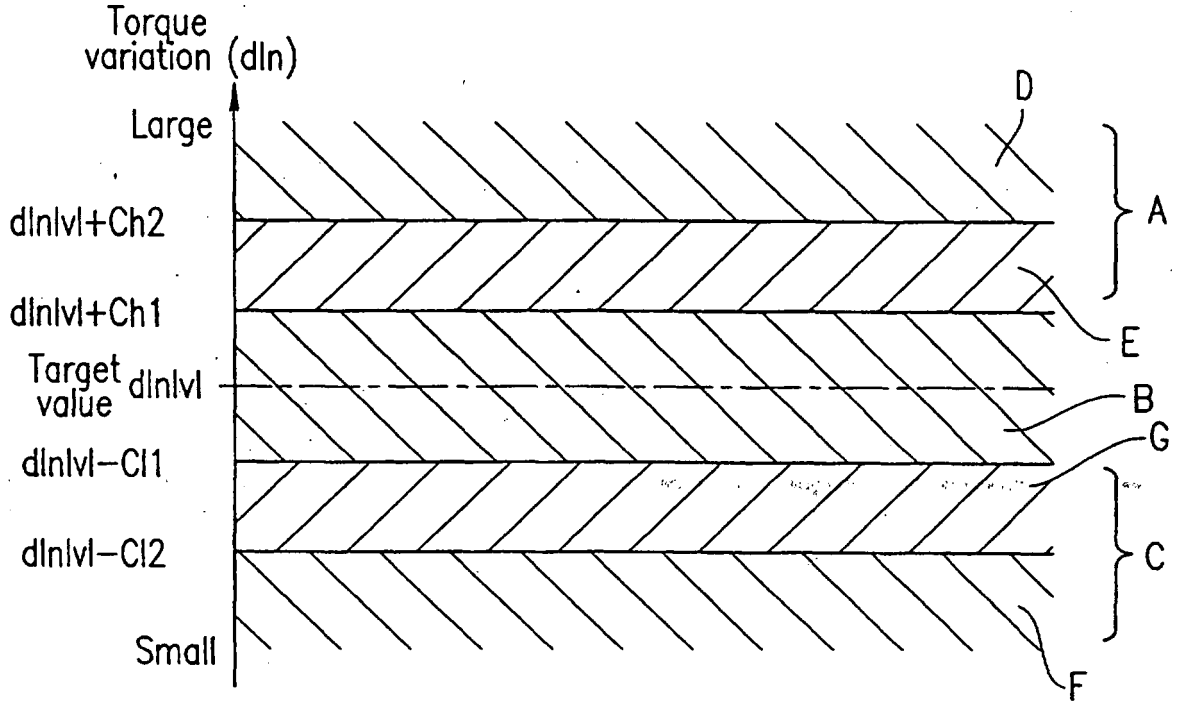

Torque variation (dIn)
Large
dInIvI+Ch2
dInIvI+Ch1
Target value
dInIvI
dInIvI−CI1
dInIvI−CI2
Small
D
A
E
B
G
C
F

*FIG. 13*

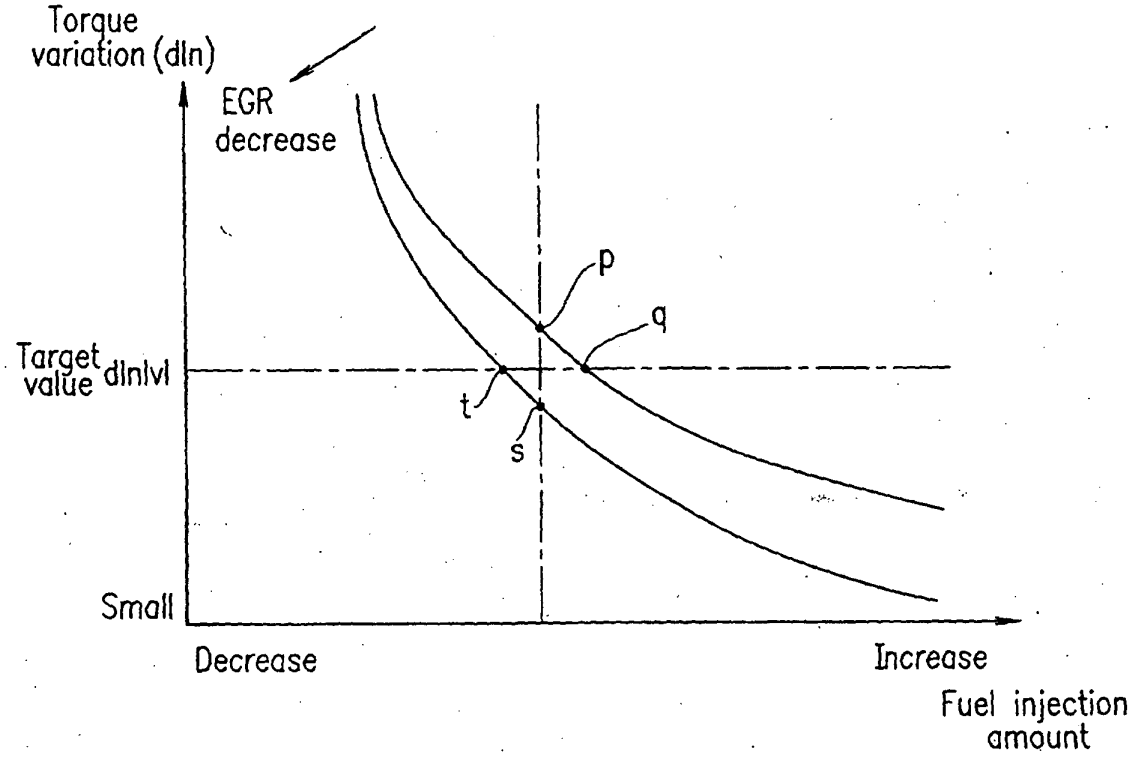

Torque variation (dIn)
EGR decrease
p
q
Target value dInlvl
t
s
Small
Decrease
Increase
Fuel injection amount

*FIG. 14*

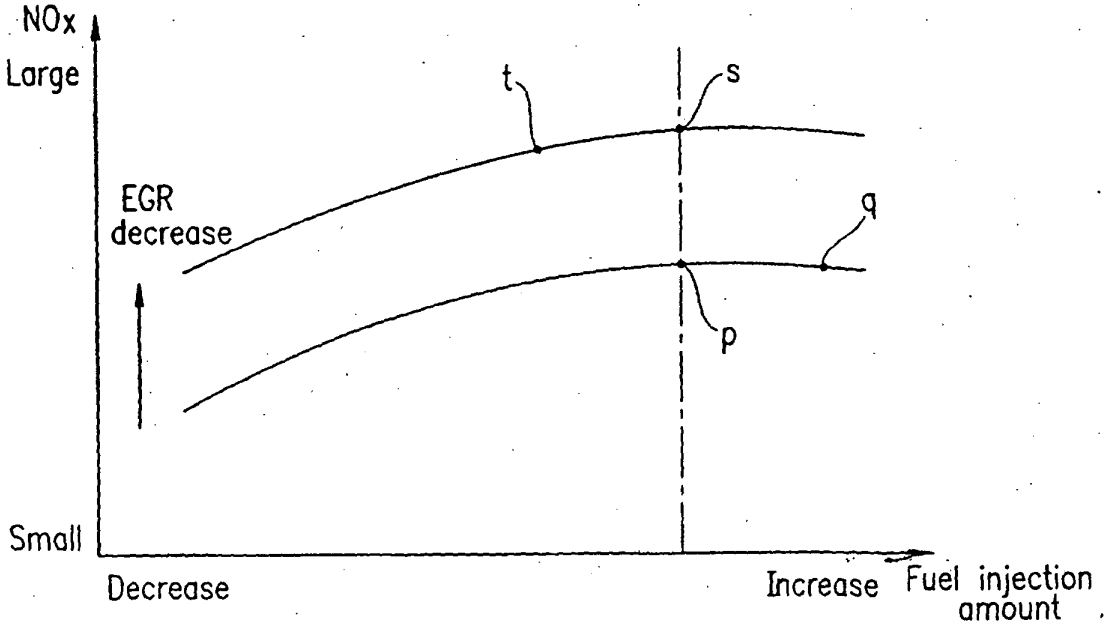

NOx
Large
t
s
EGR decrease
q
p
Small
Decrease
Increase
Fuel injection amount

*FIG. 15*

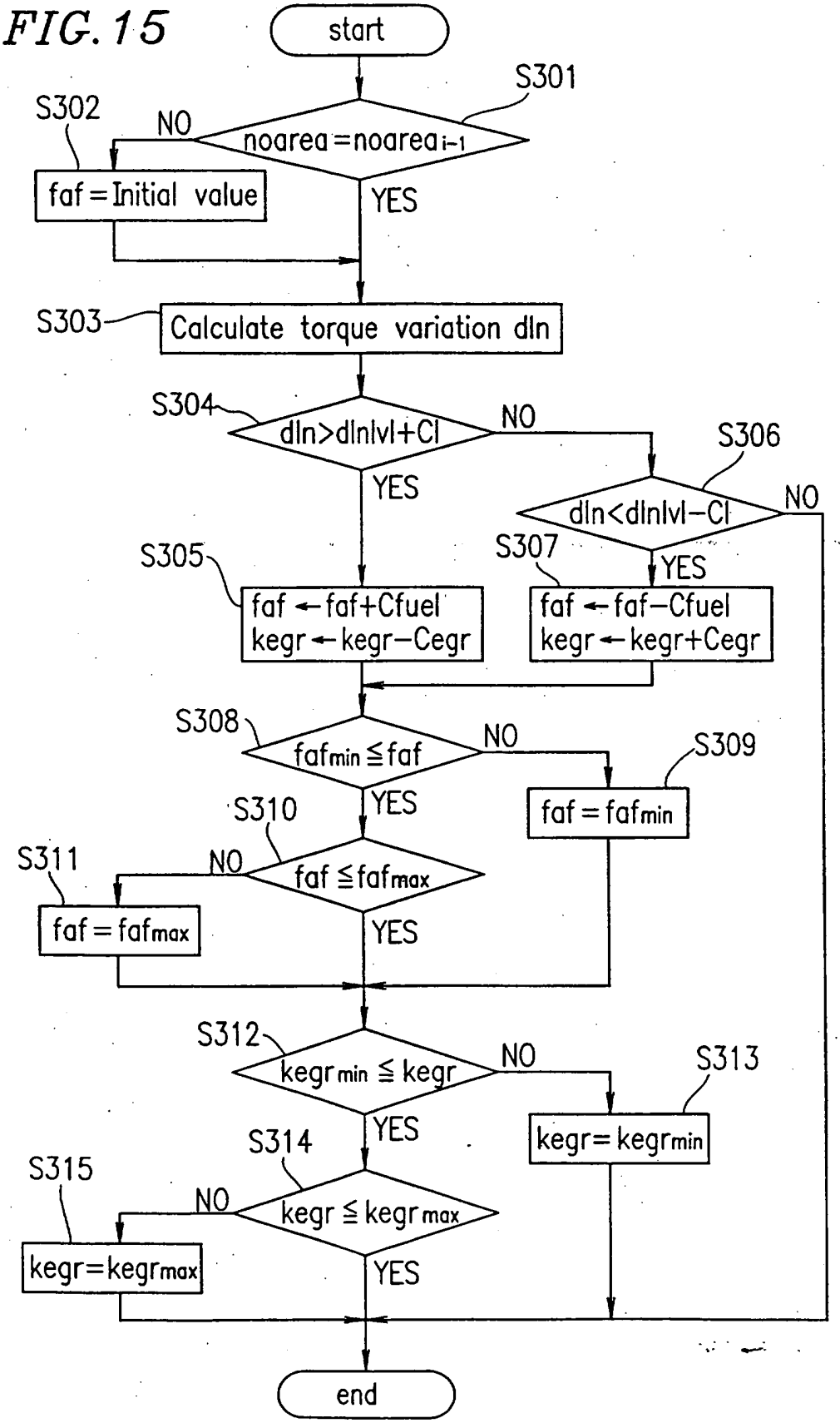

start
S301
noarea = noarea i-1
NO
S302
faf = Initial value
YES
S303
Calculate torque variation dln
S304
dln>dlnlvl+Cl
NO
S306
YES
dln<dlnlvl-Cl
NO
S305
S307
YES
faf ← faf+Cfuel
kegr ← kegr−Cegr
faf ← faf−Cfuel
kegr ← kegr+Cegr
S308
fafmin ≦ faf
NO
S309
YES
faf = fafmin
S310
S311
NO
faf ≦ fafmax
faf = fafmax
YES
S312
kegrmin ≦ kegr
NO
S313
YES
kegr= kegrmin
S314
S315
NO
kegr ≦ kegrmax
kegr=kegrmax
YES
end

*FIG. 16*

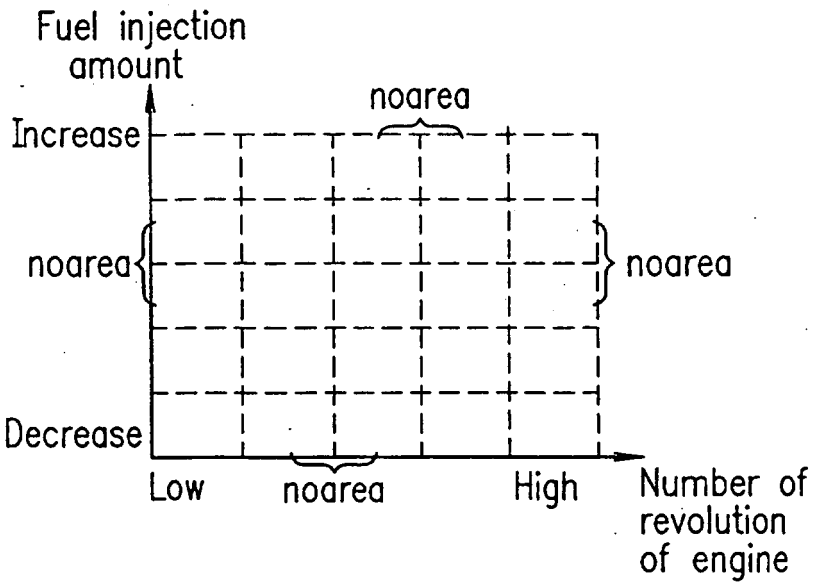

Fuel injection amount
noarea
Increase
noarea
noarea
Decrease
Low
noarea
High
Number of revolution of engine

*FIG. 17*

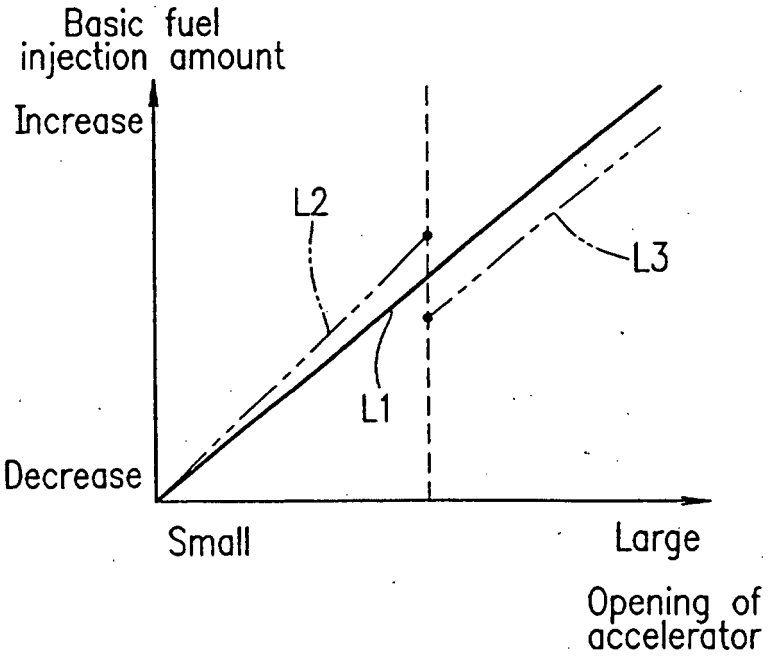

Basic fuel injection amount
Increase
L2
L3
L1
Decrease
Small
Large
Opening of accelerator

FIG. 18

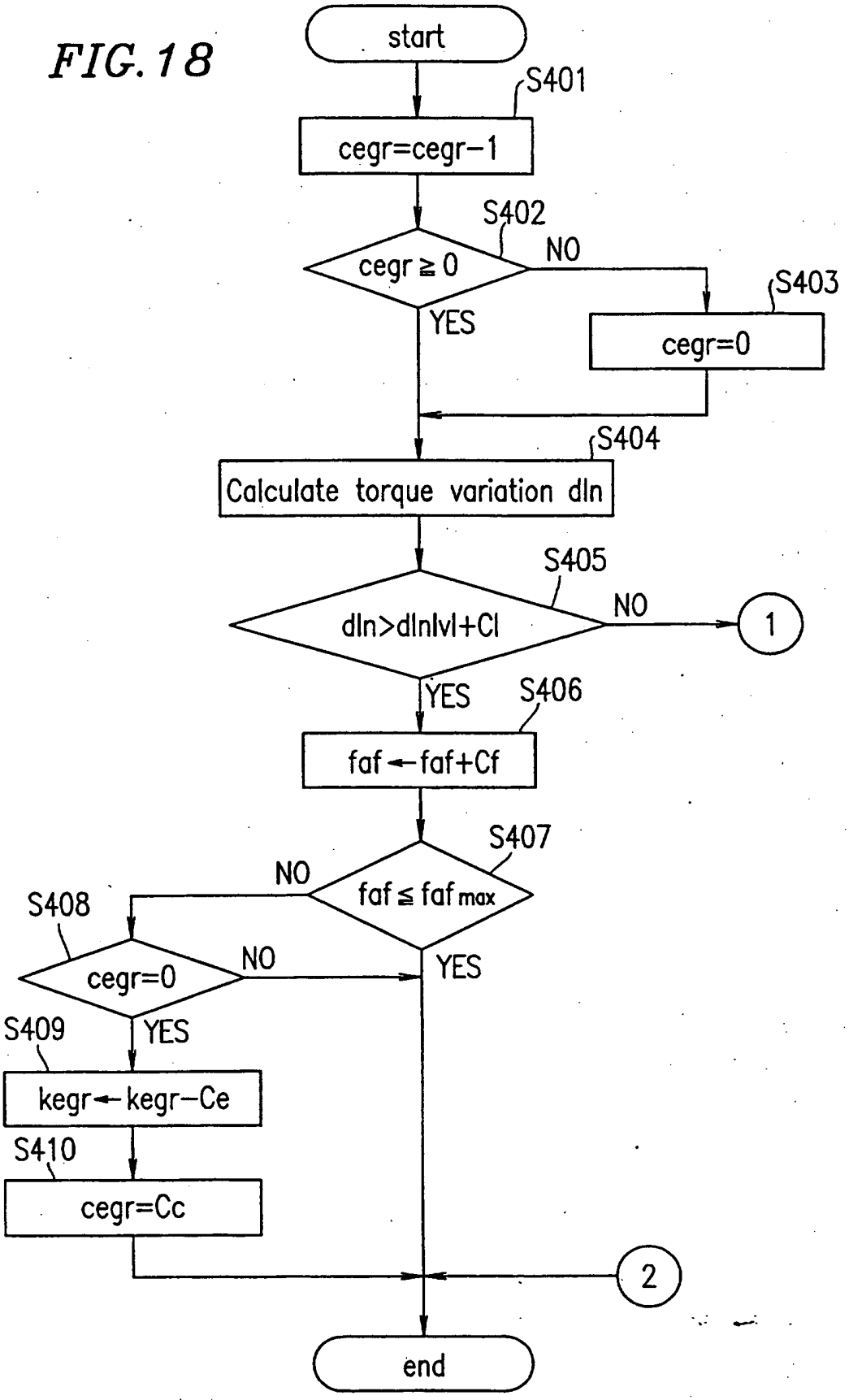

start
S401
cegr=cegr−1
S402
cegr ≧ 0
NO
S403
cegr=0
YES
S404
Calculate torque variation dln
S405
dln>dlnlvl+Cl
NO
1
YES
S406
faf←faf+Cf
S407
faf ≦ faf max
NO
S408
cegr=0
NO
YES
S409
YES
kegr←kegr−Ce
S410
cegr=Cc
2
end

*FIG. 19*

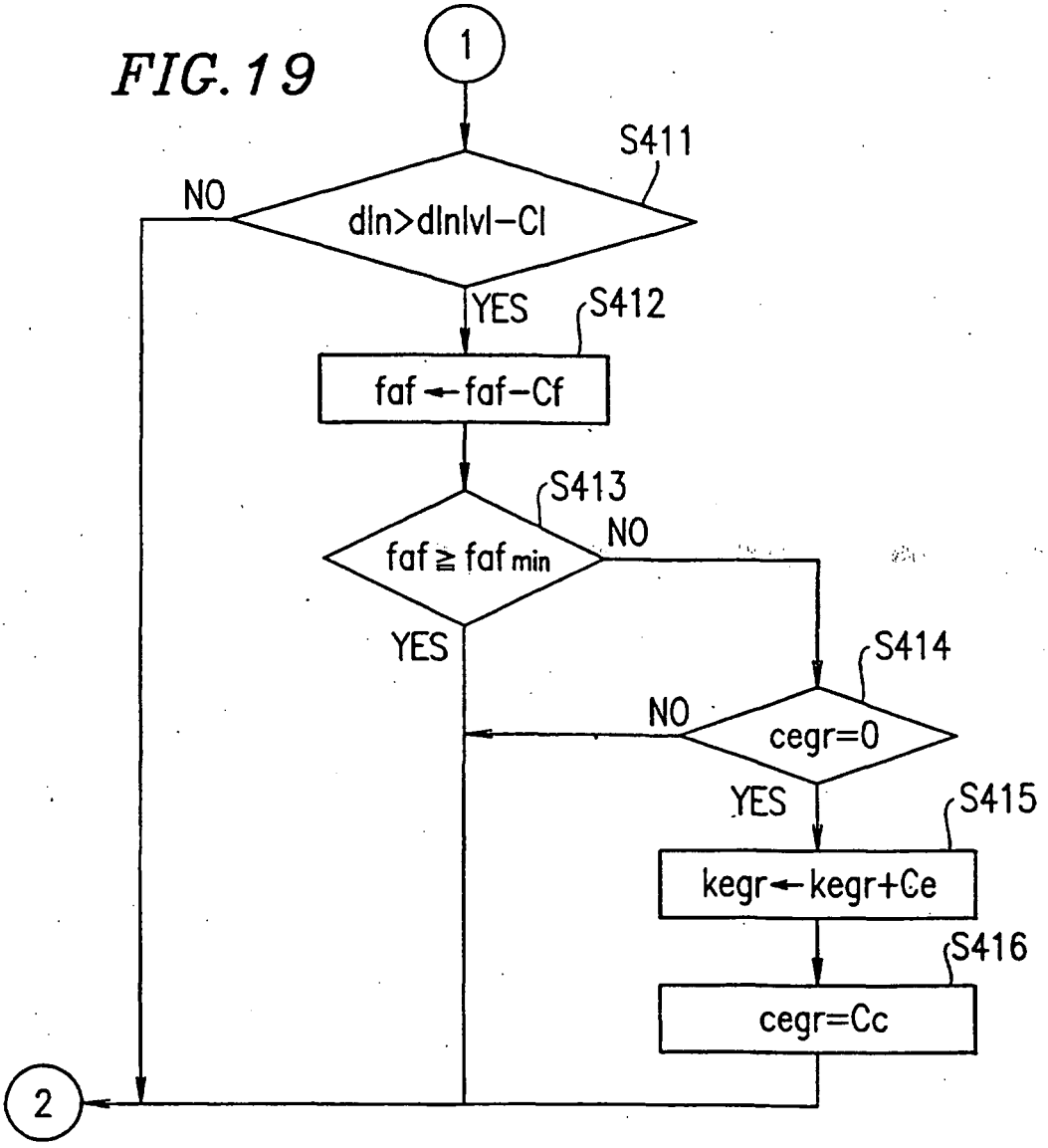

1
S411
NO
dln>dlnlvl−Cl
YES
S412
faf←faf−Cf
S413
faf ≧ faf min
NO
YES
S414
NO
cegr=0
YES
S415
kegr←kegr+Ce
S416
cegr=Cc
2

*FIG.20*

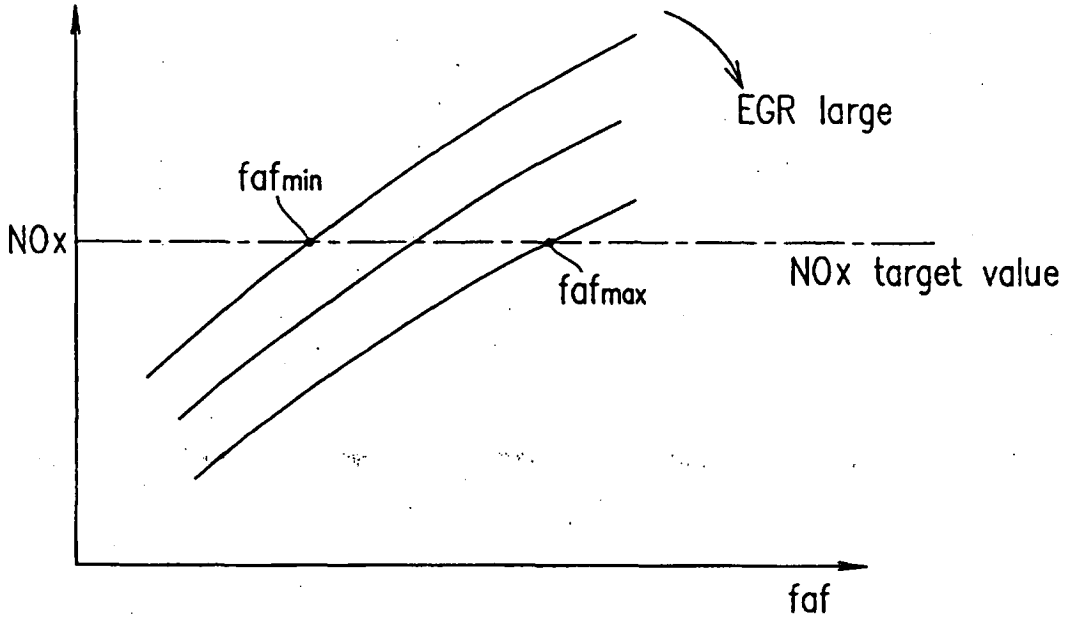

EGR large
fafmin
NOx
fafmax
NOx target value
faf

*FIG.21*

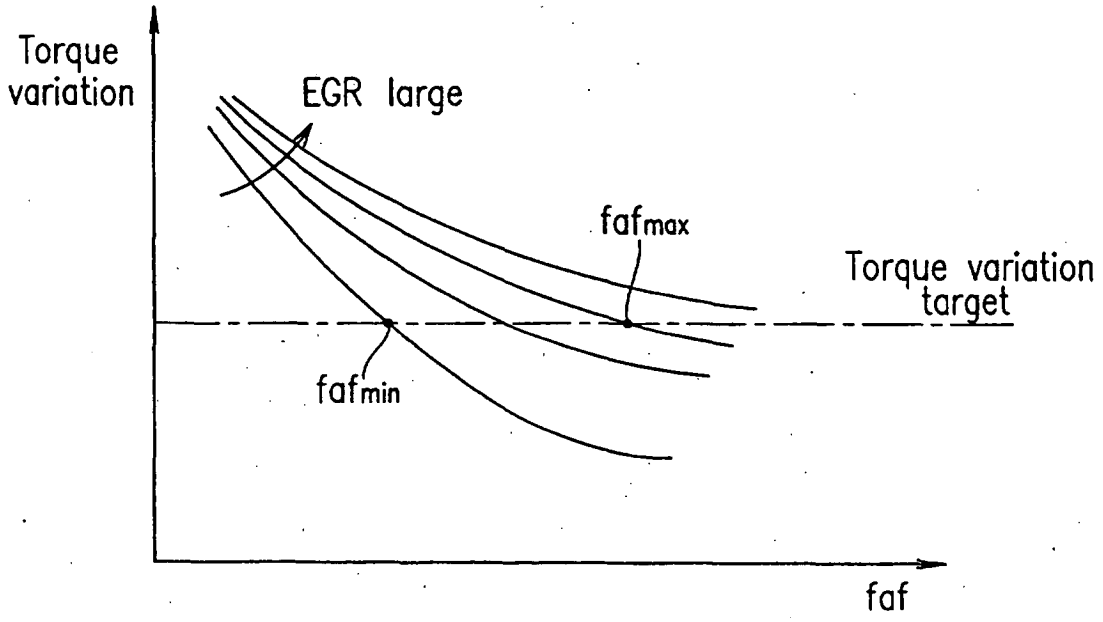
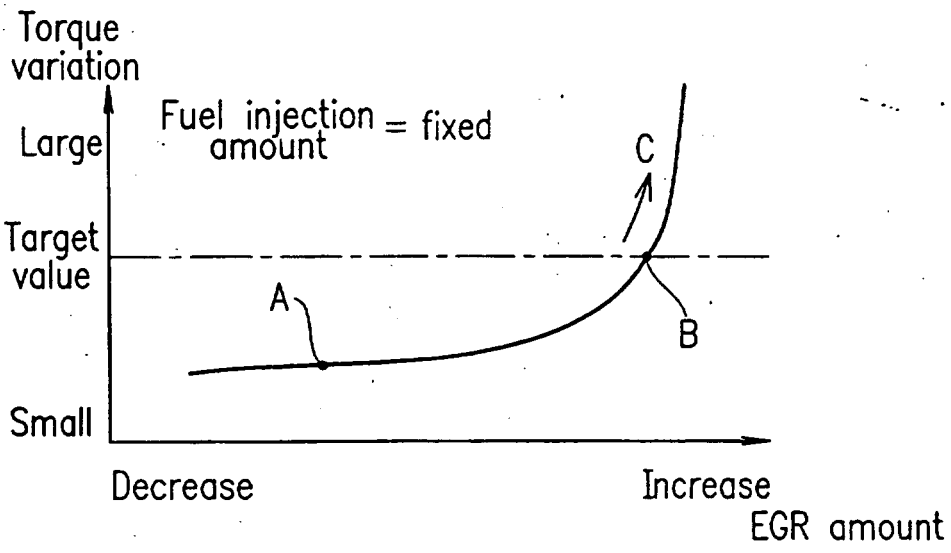

Torque variation
EGR large
fafmax
Torque variation target
fafmin
faf

*FIG. 22*


Torque variation
Large
Target value
Small
Fuel injection amount = fixed
A
B
C
Decrease
Increase
EGR amount

## REFERENCES CITED IN THE DESCRIPTION

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### Patent documents cited in the description


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- US 5265575 A **[0014]**
- DE 4303332 A1 **[0015]**